With the kindest regards of
the Author

May 1. 1909

San Francisco.

The Gateway

Journeys of Observation

By T. A. Rickard

Editor of the MINING AND SCIENTIFIC PRESS; formerly Editor of the ENGINEERING AND MINING JOURNAL; Associate of the Royal School of Mines; Member of the Institution of Mining and Metallurgy; Member of the American Institute of Mining Engineers; State Geologist of Colorado (1895-1901); Author of 'The Stamp-Milling of Gold Ores,' 'The Copper Mines of Lake Superior,' 'The Sampling and Estimation of Ore in a Mine,' 'Pyrite Smelting,' 'The Economics of Mining.'

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Author's Edition

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Dedication

To My Wife

Thy voice is as the meadowlark's that thrills
The dawn with accents rapturously gay,
And fills the toiler in the waking fields
With hopes of a diviner day.

To look on thee is as the sight of land
To weary mariners compelled to roam,
As light to those who watch for dawn,
Or to the exile, home.

The thought of thee is as the summer air
That melts the unrelenting snows,
The soft refrain of some sweet song,
The perfume of a rose.

T. A. R.

Berkeley.
September 1. 1907.

Gift
Scott Turner
10-29-52

Preface

This book records the observations made by a traveler who happened to be a mining engineer; it is supposed to belong to the type of *voyages metallurgiques*, such as were published in days before the globe had been over-run by tourists and its distant corners rendered commonplace by the exaggerations of the daily press. To the members of my profession the comment concerning the industrial conditions, geological structure, mining methods, and metallurgical practice of southwestern Colorado and a progressive part of Mexico, will have the interest that comes from observations which reflect a point of view somewhat similar to their own, while to the layman the not too severely technical descriptions, aided by beautiful photographs, will afford information of a kind rarely obtainable except in periodicals devoted to technology. It is hoped that this record of conditions in two representative mining regions may have a historical value in the days to come. Moreover, I have thought it well to publish this volume as an expression of thanks to those who were kind enough to give me many valuable data and to make my travels pleasant by their courtesy and hospitality. I am indebted to many friends for the photographs, for only a few of them are my own. From the United States Geological Survey were obtained half a dozen of the best views of the San Juan; other acknowledgments appear in the text.

T. A. RICKARD.

San Francisco, September 15, 1907.

Among the Mines of Mexico

Being the record of a journey from New York to Mexico, together with a description of the mining industry of El Oro, Pachuca, and Guanajuato, as observed in October, 1905. Reprinted by permission from the MINING AND SCIENTIFIC PRESS.

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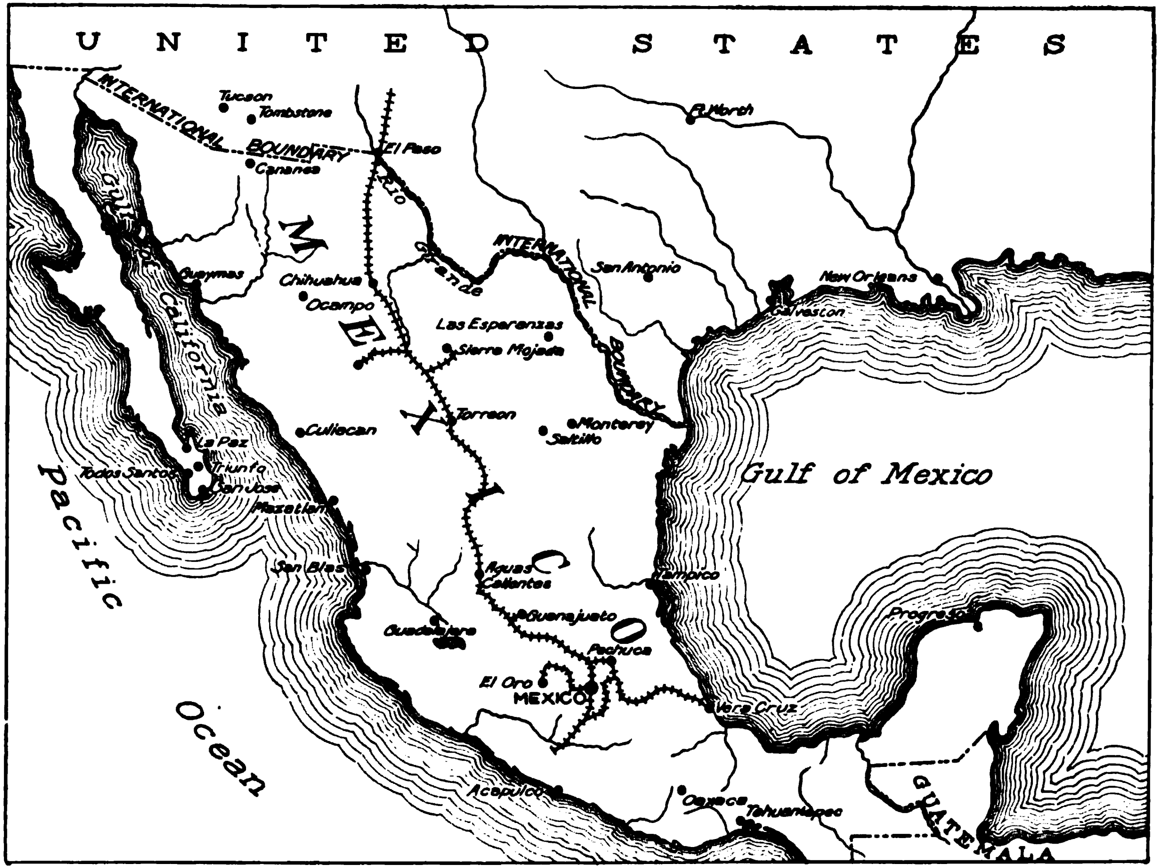

MAP OF MEXICO

Among the Mines of Mexico

Chapter 1

NEW YORK FROM THE HARBOR—A FAREWELL TO MANHATTAN.

HE tide was sweeping down the channel as the *Segurança* left her berth at the Brooklyn wharf and swung into the East river. It was a clear sunny morning early in October and the great harbor of New York looked its very best. To the sound of many whistles our steamship threaded her way among the ferry-boats and barges that congregate where, off Governor's island, the estuary separating Long island from Manhattan meets the waters of the Hudson. As we passed between Fort William and the statue of Liberty, the broken sky-line of New York City stood silhouetted against the sky. There

was just enough smoke to soften the outlines of the serrated pile of lofty buildings, which, like a Titan's stronghold, guard the great waterway. Knowing the manifold activities that have created the island city, I felt the impressiveness, rather than the poetry, of the scene. Even such smoke as came from the tall towers of steel and stone, called, with grim humor, the 'sky-scrapers,' seemed, not the incense rising from a peaceful dwelling, but the murk of battle, the confused black fog of complex strife. Despite her higher mental activities and benevolent endeavors, New York, rising proudly by the waters that made her a great seaport, is the expression in stone of a relentless materialism, a predatory finance, and a reckless luxury of life. Even the statue of Liberty, with her bronze oxidized to green and her guano-crowned head, has the air more of an old woman holding aloft a hot penny to incite a scramble among the awaiting small boys, than of the representative of a freedom long since changed to license.

As the *Segurança* turned into mid-channel we could see the dark cañon of Broadway and the series of splendid structures that line its sunless depth. Trinity church is no longer to be seen, it is obscured by a 23-story sky-scraper where congregate daily a group of men capable of running a continent—and they do their best. The financiers look down upon, and over, the spire of Trinity—in more senses than one. When Huxley came to America, in 1876, he, like all visitors, was impressed with the scene pre-

On the East River, New York

New York, as Seen from the Harbor

sented even by the undeveloped New York of that day, and seeing the yellow dome of the *World* building, which for so long dominated the high roofs of the city, he exclaimed that in approaching the shores of other lands, the first thing to be seen was a church-steeple, but that here, emblematic of the unshackled thought of a new country, the first to catch the eye was the tower of a newspaper. If he had only known for what literary sewage that yellow dome stood sentry, he, though an agnostic, would have longed to see the old-fashioned landmark. Trinity steeple is dwarfed by the Empire building, but, in compensation, the dome of the *World* building is hidden by several recent monuments to the growth of our steel industry.

As the city is left in our wake, growing dim amid its thin veil of smoke, the brutality of the crowds at Brooklyn bridge, the foul air of the Subway, the merciless sandbagging of Wall street, and the putrid politics of Tammany, are forgotten in the beauty of the harbor and the splendor of its life. Approaching The Narrows, between Staten island and Long island, the white hulls of the battleships at anchor off St. George, the swift passage of a handsome yacht, the slow procession of barges crossing to Brooklyn, the stately sailing ships preparing for a long voyage, and the majestic movement of a huge Atlantic liner coming to port, all emphasize the multiplicity of a throbbing life, the pulsations of which are felt the world over. And so, farewell, thou Empress City of

the New World, thou hast the respect received by those that have power, and the admiration due to those that are magnificent; if thou dost not win the love awakened by kindly deeds and homely service, thou reckest not. Men may come and men may go, as long as steel is strong and gold is good!

Central Park and Albisu Theatre, Havana

Chapter 2

HAVANA—A CIGAR FACTORY—THE SPANISH CONQUEST—HERNANDO CORTEZ—THE FIRST SIGHT OF ORIZABA.

IT was four days to Havana. The port is guarded by the Morro, a castellated fort standing on a promontory to the left of the entrance. During the late Spanish-American war, Morro castle was often busy, but it did no execution until the last day; in fact, after the armistice had been signed at Porto Rico. On that solitary occasion a shell went through the *New Orleans*, a cruiser, from stern to bow, between decks, killing no one, but playing sad havoc with the officers' quarters. Within the harbor, one is still reminded of the late unpleasantness by the remains of the sunken battleship *Maine*. The military mast and a portion of the 'strong-backs,' or iron superstructure, project above the water. To them I saw attached a metallic wreath on which was inscribed *Memori Missouri*, evidently placed there by the men of another battleship. The *Maine* was blown up on February 16, 1898, and I recollect the stir it made in distant lands, for on that day I happened to be at Cairo, Egypt, where everyone in the Anglo-American col-

ony confidently accepted the tragedy as the forerunner of war. There have been many discussions as to the responsibility for the crime, but it is generally accepted among the well-informed that it rests upon the *partido revolucionario*, the revolutionary party in Cuba, whose object it was to embroil the United States in war with the Spanish Government. How well they succeeded, all the world knows.

I shall not try to give any account of Cuba, even at second hand, for is it not told, and told well, by Robert T. Hill, whose 'Cuba and Porto Rico,' is a monument to his insight and industry. Cuba is a lovely island, about the size of New York State, covered by good soil and possessing a wonderful variety of economic resources. Only 10 per cent of the island is cultivated; in the valleys of the western hill-country is grown the tobacco that has done so much to soothe mankind, to express the courtesy of the civilized, and to promote the friendship of the thoughtful. Naturally, I went to a cigar factory and bought some real Havana cigars on the spot, fresh from the making. In a large room about a hundred men sat in rows before small tables, like school-boys' desks. They were wrapping the tobacco leaf into cigar form. As they worked, a man standing on a stool read to them from the daily paper; he read dramatically and well, the purpose being to keep the workers interested. The proprietors of such establishments encourage this practice, which is general, because the men do not talk while the reading proceeds. When a Span-

The Harbor of Havana

Cabañas Castle, Opposite Havana

iard talks he uses his hands in gesture, hence he can not employ them in labor; therefore the reading encourages efficiency. The men pay 10 cents per week from their wages ($3 per day) to the reader, who, in large establishments, makes as much as $125 per month.

Most travelers have spoken of the unhealthiness of Havana, of the dirt and filth that force their contrast with its beauty and color. Whatever criticism may be passed, by an unfriendly historian, on the American interference with Cuban affairs, it is certain that the sanitary measures undertaken after the war have wrought wonderful improvement. Garcia, Palma, even Sampson and Schley, were great men, but greater than these were George Waring and Leonard Wood, who did more for civilization than the leaders of war. And theirs was a contest with dangers as great as come to those on the battlefield, for Waring died, the victim of the yellow fever that he almost eradicated.

But Havana interested me most as a link in the story of Spanish conquest. Hernando Cortez, after outfitting at Santiago, called at the port of Havana before starting upon his great quest, on February 10, 1519. His fleet consisted of eleven vessels, more than half of them open brigantines, and the biggest not to be rated at over 100 tons. Thence he went to the coast of Yucatan, making a halt at the island of Cozumel, before proceeding to the mainland of Mexico. He landed at Vera Cruz on April 21. We

followed nearly in this course, for from Havana we went to Progreso, the port of Merida, which is the chief city of Yucatan, and from there we also went to Vera Cruz—as did Cortez—on our way to Mexico City. The parallel served to emphasize the difference. Cortez and his buccaneers went through uncharted seas and to a land they knew only by rumor; to them the West was full of an unlocked mystery and the place of untold gold; to us there was keen interest and expectation also, but it was an interest toned by experience and an expectation limited by knowledge. However, even the *conquistadores* can have had no more discomfort or have used language more picturesque than the passengers of the *Segurança* when we lay off Progreso for three days at the mercy of a 'norther,' or north wind, which prevented the captain from unloading his cargo or coming to anchor. Progreso is an open roadstead, and when the north wind blows, the lighters that tranship the cargo of the larger steamers are afraid to leave the shelter of the wharf; hence wearisome delays such as ours. And when the sea calmed it was painful to watch the unintelligent manner in which unloading proceeded. Among other consignments there was one of 40,000 bricks; the passengers, eager to see the steamer on her way, watching the wretched *peones* removing this cargo from the hold, suffered with an impatience only to be surpassed by the mortification of the consignee, who must have paid heavily for his bricks only to receive them in a badly

battered condition. Don't ship brick from New York to Yucatan!

Between New York and Vera Cruz we saw no mines; nevertheless, it will be interesting to refer to certain facts of history. The first of these islands (afterward called the West Indies) to be colonized was Hispaniola, subsequently known as Hayti and Santo Domingo. The great admiral, Columbus, had discovered it in 1492 and it was he that named it 'Little Spain.' At Isabella and Santo Domingo were founded the first settlements made by Europeans in the New World. Hispaniola was rich in gold, for the early records make frequent mention of the mines; these were the Buena Ventura placers and other diggings in the Cibao region where the forced labor of natives was employed, often in a cruel manner, to wash the gravel. Spanish estimates of the production—according to my friend, F. Lynwood Garrison—range from $200,000 to a million dollars per annum during the first quarter of the sixteenth century. The chief mining towns were Cotui and La Vega; as far as can be judged, the gold came chiefly from the erosion of small stringers in the diorite of the Cibao range.

It was the impoverishment of these mines that led to the colonization of Cuba. This island had been named Juana, and then Fernandina, but the Indian name has survived all the Spanish christenings. Cortez was a member of the expedition sent by Velasquez, the governor of Hispaniola, to conquer

Cuba, in 1511. Subsequently, but before he invaded Mexico, he was one of those that secured an estate there, living on his plantation and introducing some of the first of the cattle that were brought to Cuba. It is interesting to note that Cortez settled at St. Jago, a name since corrupted to Santiago. He is said to have worked for gold within his domain, the deposits promising better than those of Hispaniola. But Cuba never produced much gold; it is true that the first Spaniards found the natives in possession of personal ornaments made of gold, but these represented the metal gathered in small quantity and during a long period. The extermination of the aborigines prevented their tyrants from learning anything about the source of the metal. Since that day Cuba has won a position as a mineral region, but this is due to her deposits of iron and manganese, together with those of copper, which occur within a few miles of Santiago, where Cortez was *alcalde*. Across the bay, in the mountains of Cobre, are the ancient mines whence the great *conquistador* derived both his gold and copper. The development of these deposits has been revived since the Spanish-American war and it is to be hoped that they will become the basis of steady industry.

At last, three days overdue, we arrived within sight of the Mexican mainland. It was a sunny morning, with a breeze raising white caps on the sea and moving masses of cloud from off the dark bank on the western horizon that marked the land of the Aztecs.

A GLIMPSE OF OLD HAVANA

The Prado, Havana

Clouds obscured the view, mountains loomed to the northward, and among them the gleam of snow; straight ahead the sun shone on the white buildings of Vera Cruz, making a brilliant fringe along the shore. But there was no sight of Orizaba, the volcanic mountain, 17,356 feet high, which rises from the flats behind Vera Cruz and forms a great landmark in this part of Mexico. Borrowing a telescope, I could distinguish, over the dancing blue waves, the yellow strand of St. Juan de Ulua and behind it the towers, graceful as campaniles, of the town of Vera Cruz. The white wings of fishing boats came into the picture, and northward forest-clad mountains rose massively, some of their summits crested with snow. But there was no peak of Orizaba. Almost by accident, I shifted the telescope to a higher angle and then, suddenly, in startling beauty, above the clouds, almost in mid-sky, there stood the vision of a glorious mountain, the sun shining on the snowfields and defining the ravines, a vivid picture, strangely silent, rising above the darkly wooded slopes that in their turn rose from white cumuli, below which level lines of heavy cloud served to accentuate the loftiness of the peak and also to divide the vision piercing the upper sky from the panorama of sea and shore. It was a delicious moment; no one on the ship had caught sight of the mountain; the unexpectedness of the apparition and the vividness of it intensified the deep delight produced by one of the most glorious pictures that ever awakened an artist

or inspired a poet. It seemed so high above all meaner things, rising sheer from the sea, the intervening flat layers of mist emphasizing the height, while the brilliant sunlight upon the snowfields made it appear closer than the lowlands at the base. In a way, it reminded me of my first view of the Southern Alps of New Zealand, as seen one morning on board ship coming from Tasmania, when the serrated peaks flanked by pine forests rose above the troublous dark green waves following in the wake of a storm. But in that picture there was a series of high crests; here, there was one in solitary grandeur and without a peer. Scenes such as these compensate for the discomforts of travel and afford a stock of impressions from which one can draw on dark days and in restful hours, when the memory harks back to the past, as to the refrain of some sweet song.

Photograph by C. B. Waite. ORIZABA Reproduced by permission.

On the Railroad above Maltrata

Chapter 3

VERA CRUZ — ON THE MEXICAN RAILWAY — TROPICAL VEGETATION—COFFEE PLANTATIONS — AT ORIZABA.

VERA CRUZ is not the dirty city it used to be; the streets are cleaner than formerly, and the erection of new wharves and quays gives the incoming traveler an excellent impression. But the back streets and by-ways are not salubrious, nor does the ever present buzzard suggest pleasant imaginings. These hideous carrion birds are seen everywhere, flopping about in the streets, perched on roofs, even dominating telegraph poles; nay, their foul black shapes obscure the blue canopy and desecrate the majesty of Orizaba.

If you arrive in the morning on the way to Mexico City, you can leave Vera Cruz in the afternoon, so as to reach the town of Orizaba by dinner time. In this way, escaping from the coast and going to an altitude of 4,000 feet, the traveler avoids the risk of the *calentura*, the fever of the tropical lowlands. The journey on the Mexican Railway is one of the wonders of the world, in respect of scenic beauty and variety of vegetation. At first the train winds

through sandhills, partly hidden by abundant green, and then over marshy ground; but this is only for ten miles, when the ascent begins, over the lower plains. Sugar and corn appear; then comes a grass country interspersed with scrub and cactus, much like Natal, only the cactus here is in greater variety and instead of anthills the surface is dotted with boulders of dark lava.

The train threads its way through rank grass and past frequent hedges of organ cactus; the scars made by the railroad, even the steepest banks, are entirely healed with verdure. When the locomotive stopped we heard the broken notes of the *orache* and there was further confirmation of the plentiful bird-life, already suggested by the nests hanging from trees and woven around the cross-bars of telegraph poles.

At thirty miles from Vera Cruz, near Soledad, the foothills are reached and in this well-watered tract the tropical vegetation is luxuriant in the extreme. The ridges of lava that mark the base of Orizaba are not at all like the Drakensberg, severely bare and drearily rugged, but they are absolutely smothered with rich verdure from foot to crest, and in the *cañadas* or ravines now visible, as the train emerges from successive tunnels, there is a foliage of increasing gorgeousness. Between Camaron and Cordoba the botanical wealth of the tropics is lavishly displayed; nature, stimulated by warmth and moisture, has clothed the earth with splendor. There are the scarlet hibiscus, purple bougainvillea, the lavender

Tropical Vegetation

A Coffee Plantation

plumbago, crimson oleander, pink azaleas, the yellow and red flags of the coleus, even magnificent orchids, with creepers of every shade of green festooning the forest.

Soon the train passes coffee plantations. The wild undergrowth has been cleared, but the larger trees are left in place, so as to give shade to the coffee shrubs (five to six feet high), which are planted between them. The young coffee shrub is delicate and must be protected from the direct rays of the sun for at least two years; maturity is attained in the fourth year. The plants live 25 years and require comparatively little care—less than sugar, for instance. Speaking of these matters, it may be noted that chocolate is indigenous to Mexico and the word itself comes direct from the Aztec *chocolatl*[1]; nevertheless, Mexico nowadays imports chocolate from Guatemala and Caracas. Shade is imperative for the young coffee plant; in many cases it is cultivated under the protection of banana palms. This is the practice also

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[1] The Aztec language is still spoken by a million people, chiefly in the States of Puebla, Jalisco, and a part of Vera Cruz; it is a semi-flectional language like the Maya in Yucatan. The Otomie is absolutely different from the Aztec; it is monosyllabic and probably older; it is spoken by less than half a million people, chiefly in the States of Hidalgo, Queretaro, and Mexico. Otomie in structure resembles Chinese and, indeed, it has been claimed that the modern Chinese immigrant can make himself understood among the Otomie Indians, but this, so I was told by Don Carlos de Landero, is neither *vero* nor *ben trovato*. "It is a mere philological analogy." However, the perpetuation of these ancient tongues is an interesting fact. Occasionally it is a nuisance, because of the difficulty of transmitting intelligence. At El Oro, for example, there are a number of men working underground that do not understand Spanish or its Mexican variation, and they have to be shown what to do by signs.

in Ecuador, Peru, and Brazil. It is said that the best coffee in the world comes from the famous Youngar valley, in Brazil, where it is grown in an old cemetery under bananas. The yield is only a few quintals per year, but this coffee fetches enormous prices. As a rule the small berries (*caracolillo*) are preferred, but the Youngar coffee is of large grain. Owing, however, to rankness of verdure, many of the Mexican plantations looked so overgrown as, by reason also of the trees retained for sheltering the coffee, to seem like the bush primeval.

Soon we saw the yellow gleam of oranges and limes amid dark foliage; picturesque hamlets appeared, with red-tiled roofs and thatched houses, and white-clad peasants. At the railway stations there was always a crowd of fruit-sellers; bunches of roses and magnificent bouquets of gardenias were purchasable for a song. But the panorama of life and color suffered eclipse as the darkness of the tropical night came suddenly, without any intervening twilight. We lost the famous view of the Barranca de Metlac, but even in the dim starlight I made out the outlines of the curved steel bridge, as the train swung round it; there was the gleam of the torrent below, a feeling of space and dark void, with the lights of dwellings far away.

For the town of Orizaba most travelers have a kindly feeling, because it brings the first sleep on shore after the sea voyage, it means a good dinner at the Grand Hotel de France and a perfect cup of coffee

made from berries grown near the neighboring town of Cordoba. Early breakfast in a *patio* (courtyard) bowered by bougainvillea, to the music of a fountain, gave the bracing morning air a perfume and a fragrance long to be remembered. The mountain is visible from the town, but the view is not impressive. On resuming the train journey, we were soon climbing a heavy grade, circling the famous Maltrata valley and ascending 4,000 feet more in a distance of 30 miles. One looks down over precipitous slopes of vivid green along narrow gorges that lead to a valley cradled among the onlooking mountains and checkered with squares of cultivation. The little huts and the clusters of trees look like the playthings of a doll's house, infinitely far away and quite detached from the busy life that throbs through the train with every effort of the locomotive. This view of Maltrata bears some resemblance to that obtained when descending from the upper to the middle plateau of the Drakensberg, Pietermaritzburg taking the place of Maltrata.

Chapter 4

THE PHYSIOGRAPHY OF MEXICO — OUTLINES OF HISTORY — AT ESPERANZA — THE MAGUEY AND PULQUE — A NATIONAL HABIT — ARRIVAL AT THE CITY OF MEXICO.

AS everybody ought to know, the interior of Mexico is a high plateau enclosed within mountains of volcanic origin; this plateau rises suddenly from the lowlands that fringe the eastern coast; it is bounded westward by the Sierra Madre mountains, a part of the American cordillera, on the farther slope of which there is a sudden descent to the coastal plains of the Pacific. In traveling from Vera Cruz to Mexico City, a part of this structure is made manifest. The *tierra caliente*, or warm lowlands, forms a narrow strip, to which succeeds the temperate zone or *tierra templada*, between 3,000 and 6,000 feet above sea-level; then, by abrupt ascent, one comes into the *tierra fria* or cold country of the high tableland, at an altitude of 6,000 to 8,000 feet. Any rigor of climate such as might be due to a high altitude is tempered by the latitude, so that Mexico City, at 7,349 feet, and a little south of

Lat. 20° North, has a temperature ranging between 60 and 75° F. the year round.

Mexico is 1,950 miles in greatest length, from north-northwest to south-southeast; her northern frontier is 1,500 miles long, while at the isthmus of Tehauntepec the breadth of land has narrowed to a neck of 130 miles, separating the two oceans.

A few dates will recall the history of the country. Cortez and his company of adventurers captured the City of Mexico in August, 1521. Three hundred years of Spanish government, varied by revolutions, ensued. In 1810 the people finally revolted against Spanish domination and after an internecine strife of eleven years, independence was gained. Iturbide, in command of the insurgent troops, marched into Mexico City on September 21, 1821. It was almost exactly three centuries since Hernando Cortez made his triumphal entry. In 1821 Mexico owned an enormous territory; besides the lands of the present Republic, she ruled Guatemala, and to the north all that part of the United States (up to Canada) which is west of the Red and Arkansas rivers. Much of this domain was lost as the result of the war with the United States in 1846 and 1847. Peace was made by the treaty of Guadalupe Hidalgo in 1848. In the territory ceded at that time was the whole of the Rocky Mountain region and California. I have never seen it remarked that while this treaty was signed on February 2, 1848, the first discovery of gold, by James W. Marshall, at Coloma, was made on the January 19 pre-

ceding, or two weeks earlier. Mexico did not know what she was losing and the United States did not know what they were gaining. It is certain that had the goldfields of California remained under Mexican rule during the days of early discovery and prolific production, there would have been complications, into which the European governments might readily have been drawn by reason of the magnitude of the prize at stake. It was fortunate indeed that California became United States territory before her mineral wealth had aroused the greed of the nations.

To return to our story; we had seen Maltrata and had reached Esperanza, 8,044 feet above sea-level. Here the plateau extends with a sandy severity reminding one of parts of Arizona; from the moist air of the tropics we had passed into the dusty winds of the highlands. To the north, Orizaba hid his great head under a panoply of cloud and over the brown plains to the west were the white summits of Popocatepetl ('the smoking mountain') and Ixtaccihuatl ('the white woman'). This part of Mexico is largely given to the cultivation of the *maguey* or aloe, the *agave Mexicana.* Just beyond Apam the valley widens, becoming one immense plantation of *maguey*, reaching in ordered sequence and in lines of mathematical regularity to the dark hills in the south. The accompanying photograph illustrates the appearance of such a plantation. *Maguey* is the plant the fermented sap of which yields *pulque*, the national drink of the Mexican.

A Maguey Plantation

THE PATIO OF THE ITURBIDE

THE PLAZA AT ORIZABA

It is the 'century plant,' which got its name from the idea that it blooms once in a hundred years; which is true enough in one sense, but the *maguey* does not bloom each one hundred years or at the end of one hundred years. It matures in seven years; at that time the central shoot springs up with extraordinary rapidity to a height of six or eight feet, and blossoms. But when cultivated as the source of *pulque*, this flowering of the plant is not permitted; as soon as the stem gives evidence of emergence, it is cut at the basal socket, so as to form a bowl in which collects the sap intended for the nourishment of the gigantic stem we associate with the 'century plant.' If the incision for the removal of the heart of the plant is done too soon or too late, it dies unproductive. The sap oozes into the socket and is removed twice a day at first, and then each morning. It collects at the rate of one to two gallons per day until, after about three weeks of tapping, the plant is exhausted. In extracting the sap, a slender gourd is used as a siphon; the operator places one end in the bowl and the other in his mouth, then he draws the sap into the gourd and pours it into a sheepskin bottle. These bottles are emptied into a pigskin bag, for loading onto the mules and *burros* that carry the liquor to the *hacienda* or farm, where it ferments over night, so as to be ready for transport to the City early next morning. In the course of travel this liquid intoxicant gains the smell of the untanned raw pigskin, acquiring a filthy odor,

so that the *pulquerias* or saloons at which it is sold give forth a noisome stench. It is the whisky of Mexico and when fresh it is said to be palatable. To me it seemed to have a smell compounded of sour milk and tainted meat; it is good only (if at any time) when absolutely fresh, that is, when drunk in the locality where it is gathered. *Mescal* and *tequila* are other alcoholic products of the *maguey*; they are derived from the distillation of the roots. From the heavy pointed leaves, five to eight feet long, the Aztec made the paper on which his picture-writings were recorded. The modern Mexican uses the fibres of the leaf, after the plant has been exhausted as the source of *pulque*, to make twine (*pita*) and rope. With it he also makes the *ayate* or coarse cloth in which earth, corn, provisions, almost everything, is packed for transport on his own or his mule's back; for instance, the pigskin bag holding the *pulque* is held in an *ayate*. It is said that 1,300,000 pesos[a] are spent each month in Mexico City for *pulque*, *mescal*, and *tequila*.

It is recognized by physicians and other thoughtful men that the drinking of *pulque* is demoralizing both physically and mentally. (So also is whisky, especially bad whisky. An observant Mexican would find abundant cause for commenting upon the demoralization of the American and Englishman that soak themselves with poor whisky and make fortunes for

[a] Throughout these pages the Mexican currency will be expressed in terms of *pesos* and *centavos*, while the gold standard will be expressed in terms of 'dollars' and 'cents.' One dollar is roughly equal to two pesos.

THE PALACE OF CHAPULTEPEC
The Residence of the President and the Site of Montezuma's Palace

The Church of Guadalupe

the distillers.) Efforts have been made to curb the habit by moving the *pulquerias* farther from the centre of the City. The chief obstacle to such regulation is the long leases held by these drinking-places.

Barley and corn, probably wheat also, could be grown on the land now devoted to the *maguey*. In these cereals the country cannot supply the needs of the population. The duty on wheat was reduced for three months in 1905 by reason of the scarcity of flour and the *hacendados* tried to put up prices by creating a 'corner.' In such matters as these President Diaz is enlightened; he abominates strikes and is opposed to monopolies injurious to the community; although there is one glaring exception to his usual methods. I refer, of course, to dynamite, in which commodity a monopoly has been legalized. This is the weak spot in his administration; some of his personal friends, and even his son, are interested in the concession that has been so hurtful to the mining interests.

We reached Mexico City after dark, but the brilliantly lighted streets and crowded thoroughfares gave an impression of pleasurable life. That night I heard a splendid band (of the police) in the *patio* of the Iturbide hotel, playing in honor of the convention of American railway passenger agents. The volume of inspiriting music awakened every corner of the building, which was once Iturbide's palace. But if the first Mexican emperor had revisited the glimpses of the moon, he would have bent his head with shame.

On the second floor, there is a corner room that once held a shrine; it was Iturbide's chapel, and now it is a trunk-room wherein are deposited the multitudinous wares of itinerant Chicago drummers! *Es triste.* It reminded me of Kingsley's words, inscribed upon the drop-curtain of the Tabor Opera House at Denver:

> "So fleet the works of man, back to the earth again;
> Ancient and holy things fade like a dream."

Chapter 5

GEOLOGY ALONG THE RAILROAD — PRECIOUS METALS IN THE VOLCANIC DUST — VEIN FORMATION — THE SULPHUR OF POPOCATEPETL.

THERE was not much geology to be deciphered along the railroad from Vera Cruz to Mexico City, except the wonderful constructive features to which the Sierra Madre Oriental and the great Mexican table-land owe their origin. The plains of the coast are made of Tertiary sedimentaries, from the actual dunes of the shore to the foothills of the Sierra Madre, where the railroad enters the Middle Cretaceous, the rocks of which are largely covered by the lava emitted from young volcanoes. At Penuela there is a quarry of Middle Cretaceous limestone, which is the stone employed in building the mole and breakwater at Vera Cruz. Coming west, between Maltrata and Boca del Monte, the railroad cuttings expose intensely folded strata, traversed by faults that divide the Cretaceous series in step-like succession. Above Boca del Monte, the sedimentaries are crowned by remnants of lava streams and volcanic dust, in part consolidated as tuff and in part loose earth, but hardly warranting the idea

once prevalent that these deposits had been accumulated by wind or, in geological phrase, were of eolian origin.

Through this volcanic material, hummocks of the Cretaceous make an appearance, as at San Andreas. The rest of the journey to Mexico City is made over plains broken by occasional rocky domes and carpeted with volcanic scoria, tuff, and *malpais*.[a] Such a formation of volcanic dust is often termed 'ash.' Ash is the product of combustion; this material is the result of violent explosion and fragmentary ejection from the vent of a volcano; it is lava that has been torn into bits by the expansive force of steam, formed by release of pressure. It is, therefore, 'dust,' that is, minutely subdivided rock. This material, call it what you may, is of interest to the miner, because occasionally, when mixed with the products of the decay of other more ancient rocks, it carries gold. Near Jalapa a large area is said to give assays of one to four grams of gold per metric ton of 2,204 pounds. Two grams is claimed to be an average, and as this material cyanides readily, it may become commercially valuable. An analogous occurrence is found in the massive volcanic rocks of the ranges northwest of Mexico City, where both the precious metals exist along zones of fissuring, to the extent of one or two grams of gold and nine grams of silver per ton. The metals have

[a]This is the word that in its corrupted form, *malapai*, is used in Arizona and the Southwest generally, to designate the black lava-fields. It comes from the Spanish *mal*, bad, and *pais*, country.

A COUNTRY HOUSE IN MEXICO

Popocatepetl

been detected in places where solfataric action is in evidence, especially along cracks in the solid hypersthene and hornblende-andesites. The richest material is found in a concretionary form, together with hyaline silica, resembling the glassy quartz of ordinary gold veins. The waters doing this work are cold. It is probable that the gold and silver are derived from the decomposition of the iron pyrite, which abounds, finely disseminated, in minute crystals, throughout the rocks of these localities. Small crystals of hematite have also been distinguished, more usually in the rotten rock. It can also be said that the greater the decomposition, the greater the concentration of gold and silver in the cracks traversing this formation. In the dry climate of the Mexican plateau, meteoric water dissolves the carbonic acid, which, sinking below the surface, exerts a solvent action. In the Guadalupe range, five miles north of the City, there are narrow solfataric vents, the warm waters of which have deposited silica in the form of quartz together with gold and silver, the first in traces and the second to the extent of eight grams per ton. These occurrences, while of no immediate commercial importance, are interesting as affording present-day manifestations of the manner in which thermal waters make ore. The same process continuing for a long period, and protected from erosion, would lead to the creation of a valuable ore deposit.

Much has been said of the sulphur in the crater of Popocatepetl and a company formed to exploit these

deposits of brimstone has obtained some notoriety. Not long ago Señors José G. Aguilera and Ezequiel Ordoñez descended into the crater and found a deposit of sulphur not more than 15 centimetres thick and so distributed as to be of no industrial value. Although exceptionally pure, the sulphur was in the form of small particles mixed with volcanic dust around cold fumaroles; these emitted steam with traces of sulphuric acid, the decomposition of which led to the precipitation of the sulphur. It was the result of deposition for a period of twenty or thirty years. There is a story—and it is Prescott who tells it—of an ascent of Popocatepetl, made by some of the men under Cortez, to secure sulphur; but these explorers did not go to the bottom of the crater, which is 800 feet below the summit; they went only as far as a fumarole on the lip of the crater. After all, the quantity of sulphur that they needed—and they took—to make gunpowder, was insignificant.

A Fruit Vendor

Chapter 6

THE CITY OF MEXICO — FIRST IMPRESSIONS — THE SCHOOL OF MINES — MEMORIES OF DEL RIO — THE METEORITES — CORTEZ.

MEXICO is the Paris of the American continent. The air is clear and balmy with the feel of the tropics, the early mornings prompt a canter on horseback in the park at Chapultepec, the story of the City gives it the dignity of history and the glow of romance, the actualities of today are touched with the silken hand of luxury; life is rich, gay, and progressive. The brutality of mere materialism and the squalid splendor of newly made wealth are not evident, the invasion of Anglo-American energy and capital has prompted many sanitary reforms and municipal improvements, but the practical man from the North is insignificant in numbers, so that while he may be partly responsible for the cleanliness of the streets, he is unable to spoil the distinction of a community, the members of which go to Paris as to the Lourdes of a fashion saint, to bring home a taste in clothes and horses that enhances the attractiveness of the daily promenade, giving grace to the Spaniard and adornment to the Mexican. Time was when the

City of Mexico was far from salubrious, when her streets were badly paved and her hotels among the worst of their kind; but all that has been changed. Of comfortable hostelries there are plenty; the restaurants afford a great variety of good cuisine, and the clubs—the Jockey, the British, the American, and several others—give sojourners the hospitality worthy of a metropolis.

There are many fine buildings in the City. The cathedral and the museum are well known to travelers; the building in which the School of Mining is now situated is more than a century old, and it is full of interesting traditions. One of the founders was Andres Manuel Del Rio, the great Spanish mineralogist, who adopted Mexican nationality; he belonged to the Freiberg school, and during Humboldt's time was sent by the Spanish government to Mexico with a view to stimulating mining education. He founded the collection now to be seen in the School of Engineering, which includes that of Mining. There is a story told of Del Rio and Humboldt that is not without humor. Del Rio found a new mineral, which he called *plomo rojo de Zimapam* or red lead; it was a vanadate of lead, vanadinite. Humboldt visited Mexico at that time—between 1804 and 1808; Del Rio gave him a specimen and his notes concerning the discovery of the new mineral. Humboldt took them to Europe with him; subsequently, he wrote to say that he had lost these notes and the specimen itself in some boxes that fell overboard at sea. But,

strange to say, a few years later the vanadium mineral was discovered in Scandinavia. In 1836 Del Rio made a sarcastic reference to the episode in a paper that he wrote as a sort of protest against the injustice done to him, in calling the new metal after the Scandinavian goddess instead of—for example—Riita. For his was the discovery.

In the museum there are some fine meteorites; one specimen weighs 14 tons; it came from Chihuahua. Another, called the San Gregorio mass, has inscribed upon it the following Spanish rhyme:

Solo Dios Con zu-Poder
Este fierro destxuira
Per ce en el Mundo no Abra
Quien lo pueda Defacer.

I trust no scholar, critical of the Spanish of this quotation, will impute its apparent errors to me. I give the words exactly as I copied them from the inscription. Which may be interpreted: "Only God with his power can destroy this iron, for there is no one in the world who is able to unmake it." It was discovered in the year 1600 and weighs 10,000 kilograms; the locality whence it came was San Gregorio, in the De Allende district of Chihuahua.

From the observatory on top of the building there is a splendid view of the city and its environs, especially eastward, where the towers of the cathedral and the domes of the churches of the Profeso and Santa Teresa rise finely above the multitudinous

buildings, cut into squares by straight streets, beyond which are the dark foothills, dominated in the distance by the broken crest of Ixtaccihuatl and the big cone of Popocatepetl. To the southeast, one can see Iztapalapan—now Istapalapa—where, on the eighth of November, in 1519, Hernando Cortez met Montezuma, and the pioneer of European invasion exchanged courtesies with the poor king whom he so utterly destroyed within less than a year.

At that time Iztapalapan was a place of twelve thousand houses and it was under the rule of Cuitlahua, the brother of Montezuma. Through the town passed one of the three great causeways that led across the lake to the City of Mexico itself, and it was over this causeway that the Spanish adventurers made their way. Today Istapalapa is a small village and where once spread the waters of the lake, there is marshy ground. The causeway is obliterated by a modern street, that of Acequia, which took advantage of the secure footing thus afforded. It starts from the portals of the Plaza de la Constitucion, as does also, in the opposite direction, northward, the San Andreas street, which merges with the road to Atzeapotzalco; this was the line of the causeway to Tlacopan or Tacuba along which the Spaniards retreated on the occasion of the *Noche Triste*, that black night of July 1, 1520, which saw them all but annihilated by the fury of the Aztec populace. At Popotla the survivors halted under a tree that exists

to this day. It is now guarded by an iron railing, but despite even this protection it is endangered, for I read in the daily paper, during my visit, of the arrest of a vandal, who wanted a piece of the bark to add to his collection of curios. If ever there was a time in the Spanish conquest when Cortez and his fellow pirates were heroes indeed, it was just after their sad halt at Popotla. Of the number that had entered the City only a third (250) of the Spaniards survived and of their native auxiliaries only one fifth (1,000). They had lost most of their horses, all their artillery, all their muskets, so that there remained only their swords and their courage. But Cortez faced the music like a man and was confident even in the hour of deepest gloom. Scarcely one week later, on the plain of Otumba, this handful of men met a multitude of natives, estimated all the way up to 200,000, and beat them off the field, mainly by reason of the desperate resolve of a few of the cavaliers, who followed the immediate lead of Cortez and penetrated the thick of the combat in order to kill the chieftains on the opposite side. It may have been comparable to the attack of a centre-rush of a senior football team into the midst of a kindergarten, but it was rendered magnificent by reason of the astonishing disparity of numbers and it proved abundantly that the superiority of race was not due to physical strength alone.

It is a fact, both significant and pathetic, that

while there are today several statues to the last Aztec king—Guatemotzin or Cuitlahuac—more particularly the fine monument in the Paseo de Reforma, and while nearly every city in Mexico has a bust of Hidalgo, the priest who started the final revolution against Spanish rule, there is no statue to Cortez in the whole length and breadth of Mexico.

The Casa Blanca, at El Oro
Residence and Office of the Manager of the El Oro Mining and Railway Co., Ltd.

THE TIMBER CAMP OF THE EL ORO MINING & RAILWAY CO.

Chapter 7

EL ORO — RICH MINES — THE GEOLOGY OF THE DISTRICT — THE MEXICO MINE — THE STRUCTURE OF THE LODES — IN THE EL ORO MINE — A WIDE LODE-CHANNEL — FAULTS.

FROM Mexico City I went to El Oro. This mining district is 90 miles northwest, and while most of it is within the State of Mexico, its northern portion extends into the adjoining State of Michoacan. At the time of my visit (October, 1905) El Oro was attracting much attention; a new orebody in the Esperanza had sent up the shares (of the company owning that mine) in London; El Oro Mining & Railway Company shares had risen in sympathy; Dos Estrellas was making a boom market in Mexico City; and Victoria y Anexas was fluctuating in a manner beloved of speculators. As a foundation for such financial activities, I found lodes of unusual geological interest and a metallurgical practice that represented the sum of great technical ability.

The mines are situated on the slopes of a ridge that rises 600 feet above the valley, through which runs the old main line of the Mexican National Railway. On the near (eastern) side are the Mexico,

Esperanza and El Oro mines; on the farther slope is the Dos Estrellas. The three mines first mentioned follow a series of veins of which the San Rafael is chief; these dip into the mountain. The Dos Estrellas, on the other side, also dips to the west. The bush-covered summits of the ridge consist of an andesite lava, while the mine workings are mainly in shale. A covering several hundred feet thick of (probably Pliocene) andesite is spread over the ancient eroded surface of a (probably late Cretaceous) shale, in which occurs a series of quartz lodes, containing gold and silver. The cap-rock forms part of an extensive extrusion of volcanic material, the main vent of which is not known; although in the mines there have been encountered tongues and irregular bodies of the same rock, suggesting many minor places of emission. The shale is thinly laminated, black, and calcareous; it contains occasional layers of limestone. According to Robert T. Hill, it is the formation in which occur many of the best mining districts of Mexico. The relation of the cap-rock, the shale, and the quartz lodes is seen best in the Mexico mine, which, being a young property, is easily accessible throughout. The accompanying cross-section (Fig. 1) through the main shaft is based upon a tracing given to me by Mr. Fergus L. Allan, superintendent of the mine.

The shaft goes through the andesite of the cap-rock for nearly 600 feet and then penetrates the shale. After passing through this shale for 450 feet, the

Statue to the Last of the Aztec Kings

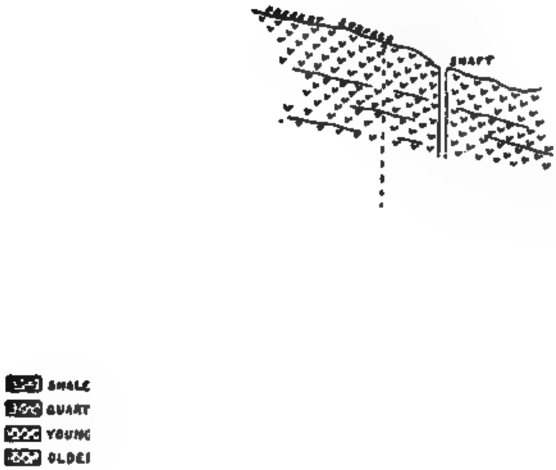

FIG. 1.
CROSS-SECTION THROUGH MAIN SHAFT OF THE MEXICO MINE.

shaft encounters andesite and continues in that rock to the bottom, just below the sixth level. This andesite, in the foot-wall country, is the same rock as the cap; it is evidently younger than the vein and, therefore, later than the other andesite, which overhangs the San Rafael vein, as seen in the first four levels west of the shaft. Some distance west of the San Rafael vein, in the Nolan mine, narrow intrusions of this younger andesite have been found running at right angles to the course of the vein. The deeper levels have not found the older andesite on the hanging wall; it antedates the vein, for mineralization extends into it. The same tongue of andesite occurs in the northern workings of the Esperanza and in a similar position relative to the vein. In some places ore has been found in this andesite, where it is adjacent to an orebody in the vein.

The lode consists of banded quartz, built mainly of rock in place, which has been shattered and silicified, the whole body attaining a width of 30 to 50 feet. The ore occurs in streaks parallel to the walls of the vein, in some places combining and occupying the larger part of the space between. This quartz contains just enough iron oxide to color it; when banded it is always good, the poor portions of the vein being characterized by massive white quartz. The shale adjoining the lode is bent and shattered; it shows numerous streaks and small veins lying parallel to, and running into, the main vein. That portion of the vein which is found at the old surface

FIG. 2. CROSS-SECTION OF VEIN IN THE MEXICO MINE.

of the shale has a width of 30 to 40 feet; it had evidently undergone erosion before being covered by the later flow of andesite. As a rule, where the apex has been thus exposed to weathering, the San Rafael vein is richer than usual; it has undergone a noteworthy concentration. In the southern portion of the Mexico mine the apex of the vein is found at the surface of the shale, but farther north the vein comes to an end 100 to 250 feet below the old surface of the shale. When the vein does not reach the old surface, it frays out into stringers, bent over at their ends, as shown in Fig. 2. The particular vein shown in this sketch carries an average assay-value (11 dwt. gold and 6 oz. silver) right from the start; it widens until, at the fourth level, there is 20 feet of quartz; on the second level, only 25 feet above its blind apex, there is no indication whatever of the proximity of a lode.

The conditions just described as occurring in the Mexico mine are found in the Esperanza and El Oro workings, which extend in sequence southward.

As seen in the El Oro mine, the veins really constitute one big lode-channel with portions of country between, that is, the distinction between what is ore and what is worthless quartz is purely commercial, based on assays, and not upon geological and structural distinctions. At first the Branch vein, one member of the system, was found to be rich enough to exploit; then a smaller streak on the hanging wall of the big Main vein (the San Rafael) was worked.

and finally the foot-wall portion of the San Rafael was stoped, to be followed by the exploitation of various subordinate members of the series, as they were determined to be rich enough in gold and silver to more than defray the costs of mining and milling. A typical cross-section of the lode-channel shows sundry branch veins, then the foot-wall orebody of 35 feet, then streaks up to three feet wide between the foot-wall ore and that of the hanging, which is 40 feet wide; finally, beyond these there is the Branch vein, 5 to 18 feet wide.

At the north end of the mine the orebodies of the foot and hanging are separate; they come together in a distance of 700 feet and form one width of 80 feet, which is maintained nearly to the south end of the shoot, in the vicinity of the incline shaft. The ore on the hanging is fairly uniform in value across its full width, but the foot-wall ore is best on the hanging side; even after they unite the individuality of the streaks is maintained. When the bands of rich ore in this mine terminate, they do so first by narrowing, and then by the splitting or fanning out of the mass of quartz that contains them. Divergent streaks connect the various orebodies, and some of them are rich enough to be stoped. The whole lode-channel is interrupted at intervals by a succession of faults dipping at 65 to 70°, except the southernmost or diagonal break, which is 35°; all of them dip north.

Water was first struck in the El Oro mine at 425 to 430 feet below the cap—for all measurements are

made from this old surface. Maximum water was encountered at 1,200 feet. The Somera shaft began to show a heavy inflow between 786 and 1,000 feet, especially from 900 feet down; the water entered along stringers on the hanging-wall side of the lode. At 1,000 feet, the cross-cut (90 feet long) to the lode cut more water along other veins, so that when the lode was finally struck there was no great addition to the inflow. The water in the workings on the main lode remained at the 786-foot level until the lode itself was cut at 1,000 feet. The faults appear to be impervious and serve as barriers; each block has to be drained separately. At the end of the rainy season, surface-water makes itself felt in the mine, but only in the northern workings, where it seeps down through cracks in the cap-rock caused by mining operations, more particularly the large stopes on the San Rafael lode made by the Esperanza and El Oro companies near their common boundary. The rainfall apparently does not affect the inflow of water in the deep workings, the mine-water (except in the case above noted) having no direct connection with the surface.

Chapter 8

GEOLOGY OF THE ESPERANZA MINE—INTERESTING STRUCTURE—A BIG FAULT—RICH OREBODY—STORY OF THE DISCOVERY—CHARACTER OF THE ORE.

IN the Mexico and El Oro mines there is some geology, which is not particularly complicated, but the ground between, occupied by the Esperanza mine, presents many intricate problems.

There is a good deal of geology in the Esperanza, and there is a good deal of rich ore. The geological features have been carefully studied by Mr. J. E. Spurr, and the data embodied in my notes are largely the result of his work, in association with the management. The accompanying diagrams (Fig. 3, 4, and 5), and the geological plan of the second level, as given in Fig. 6, are based on sketches and a blue print given to me by Mr. W. E. Hindry, the manager. To him and to Mr. W. H. Haynes, the assistant manager, I am much indebted.

The main geological events, the results of which are evident in the mine workings, are:

1. The deposition of the shale.

2. Intrusion of andesite in the form of dikes and sills.

3. Faulting, involving several dislocations, one of which became the channel of the San Rafael lode; and later movements that displaced the lode.

4. Deposition of ore by waters circulating along the channels made by the previous fracturing.

5. Intrusion of a later andesite that overflowed at surface and penetrated the shale formation.

6. Cross-faults.

In Fig. 3 the San Rafael lode is shown as seen in cross-section, looking northwest, in the northern portion of the mine. The sequence of geological events is indicated by the numbers 1 to 5. First, the shale was ruptured and dislocated at least 1,000 feet—from 1 to 2. Then it was eroded and on it was spread the andesite, the original surface of which (at 4) was reduced by erosion to the present surface (at 5). The thickness of this andesite cap ranges now from nothing up to 700 feet. In the meanwhile the intrusions of earlier andesite were also faulted with the shale, as is suggested by a tongue of that rock indicated on the diagram. In Fig. 4 the same sequence is exhibited as is seen in a cross-section of the southern end of the mine. In this case a higher intrusion of earlier andesite is shown and also a tongue of later andesite.

The lode, therefore, follows a big fault; but it is itself faulted, as shown in Fig. 5, which is a longitudinal projection N 60° E, magnetic. On the first

Sorting Ore

On the Outskirts of Guanajuato

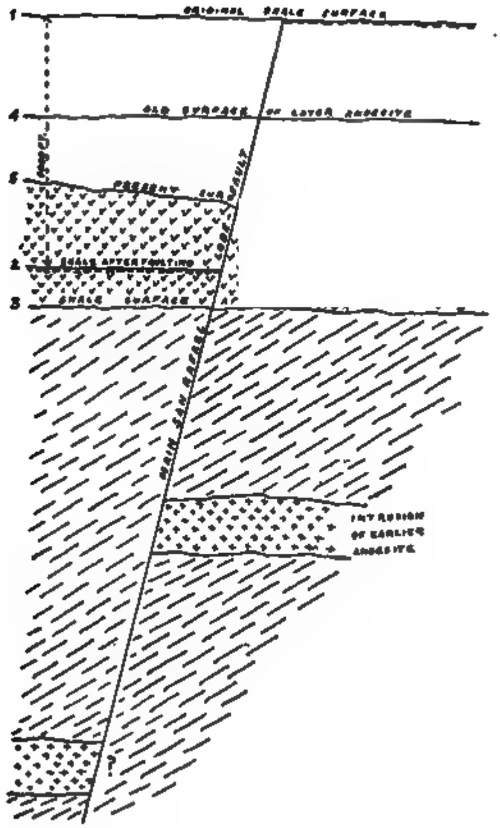

FIG. 3. DIAGRAM SHOWING THE SERIES OF GEOLOGICAL EVENTS THAT BROUGHT ABOUT THE PRESENT STRUCTURE. CROSS-SECTION OF NORTHERN PORTION OF ESPERANZA MINE.

level at a point 525 feet north of the El Oro boundary, this fault cuts through the country and displaces it, as measured by broken ends of intruded older andesite, 500 feet vertically. This same fault is evident at the surface of the shale (now buried under later andesite), for there is a drop of 160 feet in the bottom of the cap-rock. This would appear to indicate that the movement transverse to the lode continued after the later andesite overflow, so that in the main fault, the total dislocation is measured in two parts, two-thirds or about 340 feet of which occurred before the cap-rock was formed, and one-third, or 160 feet, after that event.

In the mine the lateral displacement of the San Rafael lode is 130 feet, to the right. At the south shaft the cap is 284 feet thick; near the north shaft it is 165 feet higher (by reason of the rise in the ground in a length of 1,600 feet, which is the distance between the shafts) plus the fault (160 feet), plus the elevation, making the present thickness 165 + 160 + 284, or 609 feet. South of the fault the lode is entirely in shale all the way down to the fifth level; just below that horizon there is andesite on the foot-wall and shale on the hanging. North of the fault, the first level penetrates cap-rock, while the second has shale on the foot and the older andesite on the hanging. The third and fourth levels repeat the conditions observed on the second. At the fifth (still north of the fault) there is a change; at about 100 feet in the foot-wall the newer andesite (which is

Putting Timbers in Place

A Good Lode in the El Oro Mine

the cap-rock) appears at a point 500 feet north of the fault and thence to the boundary of the Mexico mine. At the sixth level the older andesite is seen in the foot-wall south of the fault and looks like the top of an

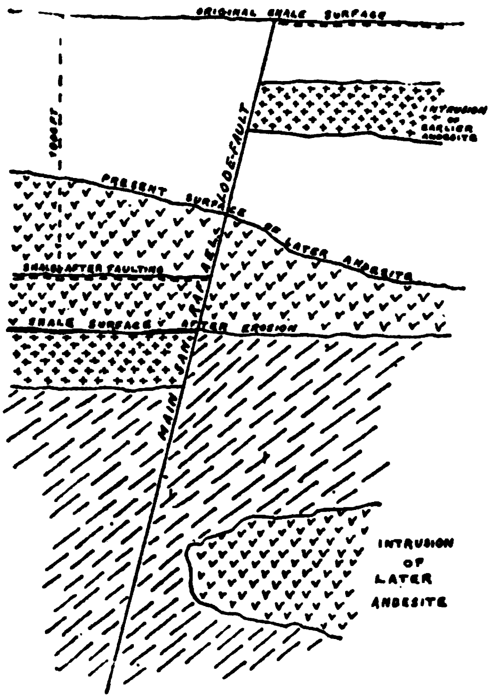

FIG. 4. LODE-FAULT, SAN RAFAEL VEIN. CROSS-SECTION OF SOUTHERN PORTION OF ESPERANZA MINE.

intrusion; north of the fault, shale appears on both foot and hanging, that is to say, we have the conditions which exist south of the fault 500 feet overhead —this being the measure of the dislocation. On the

seventh level the older andesite appears along the foot-wall up to the fault, shale showing in the hanging. North of the fault the lode is in shale as regards both walls, with the newer andesite in the foot-wall country (150 feet east of the lode) near the Mexico boundary. At this same level—the seventh—the newer andesite (or cap porphyry) occurs in the form of an east-west dike, 153 feet thick, at a point 825 feet west of the lode, but its real shape has not been ascertained.

All this refers to the San Rafael, the main lode of the Mexico, Esperanza, and El Oro mines. The interesting problem, at the time of my visit, was whether the new West vein is faulted (see Fig. 6) in a manner similar to the San Rafael or whether this bonanza vein is younger than the fault itself. If the latter be the case, the vein would go into the andesite north of the fault at the third, fourth, and fifth levels. The ore of the San Rafael extended up to the fault, the break being clean. At the fifth level pay-ore was broken almost up to the fault-line. The San Rafael is generally more broken on the north side, the ore not reaching up to the fault as clearly as it does on the south side. If the West vein be later than the fault, it is likely to be weak where crossing the latter and probably it will be less rich in the andesite than in the shale, the bonanza portions of the veins of this district being in shale country. With the limited data at my disposal, it seems to me unlikely that the new vein is younger than the fault, because there is

no evidence of its existence in the northern workings.

The new Esperanza orebody is a sight to gladden the eyes of a miner. It is 680 feet long, with an average width of 9 feet and an average yield of 75 grams of gold (or $49.70) per ton and 1,150 grams of silver ($19.55) per ton. The shape of it is roughly lenticular; it is widest about the centre and comes nearly to a point both north and south; in depth it is

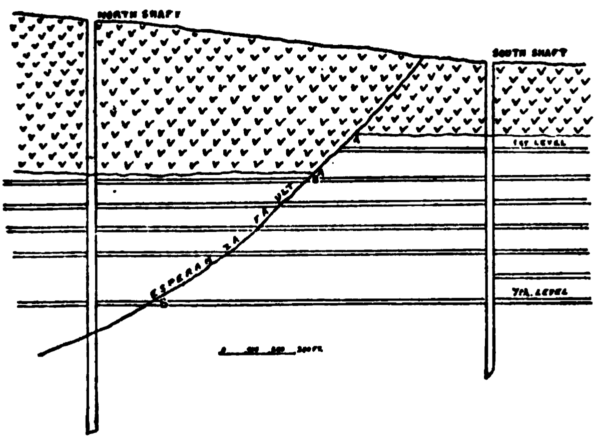

FIG. 5. THE ESPERANZA FAULT. After J. E. Spurr.

shaped like the bottom of a boat, with protruding keel. Where first cut on the fifth level, there were two veins close together; the first assayed $1.50 to $2 per ton, while the other, or No. 2, to the west, went $75 per ton. Subsequent stoping gave a different story; the No. 2 has been payable only for 50 feet above this level, while the No. 1 gets into rich ore

three feet above and only 15 feet south of the cross-cut.

At about 45 feet south of the cross-cut, the two veins come together and make a width of 35 feet of ore worth over $100 per ton. The moral is: If you find absolutely nothing by drilling, do not cross-cut; if you find any encouragement whatever, cross-cut. In the workings that I visited there were stopes four feet wide of ore worth $500 per ton; where the quartz was rich, even the adjoining shale (penetrated by small stringers of quartz) was good enough to stope, for it assayed 15 to 40 grams of gold.[4] Small bands of shale included by the vein assayed equally with the quartz. It seemed to me that, as compared with the San Rafael lode, this bonanza vein was particularly well defined; there was no gouge and the shale at the walls was broken off clean, without shattering or twisting, the bedding of the outer country lying flatly right up to the ore. The vein is apparently younger than the San Rafael, because there are few signs of later movement, such as slips or gouge-seams. The ore itself is beautifully ribboned; minute crystals of pyrite incrust the quartz, especially in geodes or vugs; the richest ore is *mosceado*,[5] that is, speckled with argentite.

On the seventh level there is an interesting vein occurrence; this is a seam of pyrite called the 'sulphide

[4] A gram of gold is worth 66.4 cents and a gram of silver 1.7c. My description of the orebody is based, it must be remembered, on notes made at the end of October, 1905.

[5] From *mosca*, a fly.

SHAFT

FIG. 6. PLAN OF SECOND LEVEL OF ESPERANZA MINE.

Geology by J. E. Spurr. Drawing prepared by the author from map by W. E. Hindry, mine manager. The apparent anomaly in geological conditions—the andesite being absent on the south side of the [illegible] the fact that there has been a vertical displacement, as well as the horizontal movement indicated. Comparison should be made with Fig. 1, this section of the Mexico mine being taken 800 ft. north of the ground shown in Fig. 6.

streak,' 26 inches wide, in the foot of the San Rafael lode, which here is 22 feet wide. The sulphide streak crosses the San Rafael and is therefore younger. The foot-wall country in this part of the mine is porphyry (andesite) and the sulphide streak is built up of brecciated porphyry, the hanging being irregular and penetrated by quartz veinlets, while the foot-wall carries a gouge, beneath which the fragmentary character of the vein-stuff is evident. This vein carries a pyrite which is coarser than that of the new West vein and in the ratio of 12 per cent; the West vein yields one ton of concentrate to 16 tons of crude ore, that is, over six per cent.

In speaking of ore at El Oro as being worth so many dollars, it is meant that it contains so many pennyweights of gold, for the silver is not included. This is largely a habit inherited from the days when the silver was not extracted in commercial quantity. A $7 to $9 (or 7 to 9 dwt.) gold ore will carry $1.50 to $2 (or 2.5 to 3.3 dwt.) silver per ton. The gold is free and in fine particles, rarely visible, while the silver occurs chiefly as the sulphide (argentite), with some chloride in the upper levels. The quartz is extremely hard and flinty, beautifully ribboned in lines parallel to the walls of the lode. In this respect and in its general appearance it often reminded me of the ore produced by the Amethyst and Last Chance mines at Creede, Colorado, in 1894. Argentite occurs along the lines of ribboning in minute streaks between seams of opalescent quartz; the natives call

A Rich Stope in the Esperanza Mine

General View of El Oro

The El Oro Mills and Shaft-House Are in the Centre

these *hilos*, or threads. The ore is largely a replacement, by silicification, of the encasing country and this holds true no less of the andesite than the shale. The Esperanza is sending mineralized porphyry to the mill and mineralized shale to the smelter. Beautiful pseudomorphs of quartz after calcite are frequent, they appear as sharp scalenohedra and resemble the 'water quartz' of Cripple Creek. The best specimens occur in the small 'horses' (or included fragments of country) within the vein and on the outside of the big pay-streaks. All the surrounding shale shows the effects of mineralizing activity and the outside andesite will often yield traces of metal; for instance, the old decomposed andesite on the fifth level of the Esperanza assayed 0.29 oz. silver and traces of gold.

At the time of my visit, at the end of October, 1905, the rate of production of the El Oro district was slightly over $1,000,000 per month, distributed thus: Esperanza, $650,000; Dos Estrellas, $240,000, and El Oro, $200,000. An output of $12,000,000, 82 per cent of it being gold, made El Oro the second most productive gold-mining centre on the American continent.

Chapter 9

DEVELOPMENT OF THE MILLING PRACTICE AT EL ORO — BEGINNING OF CYANIDATION — FIRST BIG MILL — CHANGE OF METHOD — TUBE-MILLS AND RE-GRINDING.

DEVELOPMENTS in the milling practice at El Oro are full of interest. In 1873 a *hacienda de beneficio*, or reduction plant, was erected to crush ore and treat the accumulated tailing from a still older *arrastre*,* and to this plant further addition was made in 1885. The mill then included 25 stamps with amalgamating tables. In 1890 the accumulation of tailing made by the stamps was sold to a man from Butte, named Albertson. The tailing he handled was richer than the ore being mined today. Nevertheless, the contract for the treatment of it was cancelled after the purchaser had installed four amalgamating pans, with settlers, and had started to ship bullion. This was under the regime of General Frisbie. In 1894 a Chilean mill was brought from Chicago, to grind the ore after it had passed through a Comet crusher. The Chilean mill did finer grind-

* The Anglicized form is 'arastra,' but there is no need to use it, the Spanish term itself being preferable.

ing than the stamps, which at that time were also preceded by crushers, of the Blake type. The mill in turn left a dump that, eventually, as methods improved, it became profitable to re-treat. Late in 1894, James B. Haggin bought control. In the following year the old mule-stable was converted into a cyanide annex. Redwood tanks 24 feet in diameter, with 4½-foot staves, were erected; the sump-vats were larger, with 6-foot staves. The tailing was carried, in boxes on the backs of *peones* and in hand-barrows, to the vats. Cyanide solution was first introduced by upward percolation through a false bottom, the succeeding water-washes being applied from above. This was followed by precipitation on zinc shaving, with acid treatment for the zinc 'shorts,' the bulk of the precipitate being carefully washed and melted forthwith. The bullion thus obtained was of extraordinary fineness—960 to 980—without the use of any nitre in the melting. This was one of the first successful cyanide plants in Mexico. With only the addition of the small cyanide annex just described, the mine paid $1,000,000 in dividends up to May, 1898, besides meeting the cost of various installations, including part of the 100-stamp mill taken over by the English company, which now controls the property.

The first 100-stamp mill was designed under the Haggin-Frisbie regime and was only expected to crush 4,500 tons per month through a 60-mesh screen. When the property was purchased by the Explora-

tion Company in 1898, this mill was too near completion to be altered. The slime-plant was added in 1900, after the present company had been formed. W. K. Betty had conducted a series of experiments for the new owners and double treatment was then adopted for the slime-plant. This was only making the best of conditions as they were found; hence the pile of stored tailing now about to be re-treated.

The general plan of treatment was as follows: From the stamp-battery the pulp passed over copper plates and was then divided, by spitzkasten, into 'coarse sand,' 'fine sand,' and 'slime,' each product receiving individual treatment. The sand underwent double treatment in South African style; it was first cyanided in collecting-vats and then dropped into cars that removed it to the treatment-vats. The slime was caught in a settling-vat and thence went to the treatment-house, where it was agitated by jets of compressed air. After treatment, the sand was dropped into cars underneath the vat, while the slime was flushed out with water in the ordinary manner.

In the meanwhile the capacity of the mine grew, not only by reason of the discovery of new orebodies, but indirectly through the cheapening of operations, so that further enlargement of the mill became prudent. In 1905 another, and the last, addition to the reduction plant was made. The new mill of 100 stamps, with its up-to-date cyanide equipment, differs from the old one in five respects, namely:

Fig. 7. Diagram of Cyanide Treatment at Plant No. 2 (September, 1905.)

1. Mechanical handling of the ore.
2. Heavier stamps.
3. Re-grinding in tube-mills.
4. Mechanical handling of sand by distributors, excavators, and belts.
5. Mechanical agitation of slime by stirrers and centrifugal pumps.

The new mill contains 100 stamps, each weighing 1,180 pounds, falling 102 times per minute, with a 6-inch drop. The depth of discharge is 2½ to 3 inches with a new die, and 3½ inches when the die is worn out. Woven brass wire screens of 35 mesh are used.

The accompanying diagram* (Fig. 7) illustrates the process. From the stamps the crushed ore goes to a system of cone-classifiers and spitzkasten, which separates the coarsest sand and sends it to the tube-mills for re-grinding. The fine sand from the stamps combines with the similar product from the tube-mills and is elevated by the raff-wheel to the sand-collecting vats. Any slime that may have escaped complete separation and accompanies the sand, overflows from these vats and passes to the slime-plant, joining with the rest of this product that has been eliminated from the sand by the classifiers. The sand is dis-

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*Borrowed by permission from 'The Grinding of Ore by Tube-Mills, and Cyaniding at El Oro, Mexico,' by G. Caetani and E. Burt. *Transactions* American Institute of Mining Engineers, February, 1906. This is a conscientious and most valuable paper, giving a detailed account of the cyanide practice at El Oro.

tributed by a revolving mechanism of the Butters & Mein type. There is no chemical treatment in the sand-receiver, the idea being to keep the mill-water free from cyanide while effecting a final separation of slime, so as to get a clean product. The water and slime are drawn off through gates or slots on the side of the vats; these gates are closed by a roll of canvas as the vats fill. The sand, when thus finally freed from the last trace of slime, is removed by a Blaisdell excavator, which drops it through a central opening onto a Robins belt-conveyor. This Blaisdell excavator is like a revolving disc-harrow and it has proved a most efficient machine. It uses comparatively little power and works smoothly. The belt-conveyor takes the sand (containing now only from 10 to 11% moisture) to the treatment-vat, which is fed by a revolving distributor operated by a variable-speed motor, the centrifugal force being so regulated as to throw the sand to the sides or centre of the vat, as required. The charge is 265 tons, dry weight. Ten washes of alternately medium (0.1%) and strong (0.2%) solution are introduced, six hours apart. This treatment is followed by no less than thirty 'weak' washes, such a lengthy operation being specially designed to extract the silver. These 'weak' washes are four to six hours apart and contain 0.03% cyanide. Each wash is equal to 13 tons of solution. After treatment, the residue, again using the Blaisdell machine, which moves on rails, is dis-

charged onto a conveyor that takes it to the dump. Here the distribution of tailing is regulated, as the accumulation grows, by a hinged belt-conveyor in two lengths, the last one being swung round according to the contour of the ground.

In the Market Place

Another Market Place

Chapter 10

TREATMENT OF SLIME—USE OF LEAD ACETATE—ADDITION OF LIME—ITS DOUBLE FUNCTION—SETTLEMENT OF THE SLIME—THE TUBE-MILLS—THEIR LINING—SUCCESSFUL WORK.

THE slime goes to a collecting vat, from which the thick mud is drawn off at the bottom and thrown into one of the treatment-vats. There are twelve of these, each 34 feet in diameter and 12 feet deep. Here it is agitated with a proper proportion of cyanide solution, which is introduced simultaneously. The apparatus for stirring consists of two long and two short arms made of oak. These are solid; they taper outward from a cross-section of 4 by 6 inches to 4 by 4 inches. The thick end is bolted to a steel star, which is set on a vertical shaft. When the vat is charged, lead acetate is added immediately. Tests have shown that a beneficial result ensues forthwith, particularly as regards the dissolution of the silver.

Lead salts, when added in excess to the cyanide solution, give a precipitate of basic lead cyanide, but when present in small proportion the lead remains in solution, presumably owing to the formation of

an alkaline plumbite (K_2PbO_2) by reaction with the caustic alkali, thus:

$$PbAc_2 + 4KOH = K_2PbO_2 + 2KAc + 2H_2O.$$

Mercuric chloride is sometimes employed for the same purpose, producing a reaction with the KCy so as to form a soluble double cyanide, thus:

$$HgCl_2 + 4KCy = K_2HgCy_4 + 2KCl.$$

The most useful effect of these soluble lead and mercury compounds is the removal, in the form of insoluble HgS and PbS, of any soluble sulphides that would otherwise retard the solution of gold and silver, and might even re-precipitate silver already dissolved:

$$K_2S + K_2HgCy_4 = HgS + 4KCy.$$

$$K_2S + K_2PbO_2 + 2H_2O = PbS + 4KOH.$$

The double mercuric-potassium cyanide also acts as a solvent, attacking gold more readily than simple KCy; and this action is independent of the presence of oxygen, gold replacing mercury:

$$K_2HgCy_4 + Au = K_2AuCy_4 + Hg.$$

Silver is similarly dissolved. These reactions have been amply verified. The action of mercuric-potassium cyanide on gold is the basis of patents secured by Keith and Hood; the latter also claims the use of lead as facilitating the solvent effect of cyanide solutions. De Wilde has a patent involving addition of lead oxide to the cyanide solution. These compounds also influence precipitation beneficially if they remain in the solution up to the point of entering the zinc-box, as in that case the lead and mercury are precipitated on the zinc, forming zinc-lead and zinc-mercury

couples of high electro-motive force. In this precipitation the zinc simply changes places with the mercury or lead, as is also the case when zinc shaving is dipped in lead-acetate solution.

The charge is 60 tons (dry weight) of slime; this is mixed with a solution in the proportion of 2½ solution to 1 of slime, by weight. The solution contains 0.05% cyanide.[7] Agitation continues for six hours. The vat is then filled until there is 3½ of solution to 1 of slime; this is well stirred and then allowed to settle. Settling and decantation consume eight hours. This part of the process is hastened by the use of lime, which is added to the feed of the tube-mills.

The lime has two functions, one of them chemical, the other physical. By virtue of the first it neutralizes the sulphuric acid and decomposes the ferric sulphate contained in the ore, and due to oxidation. Such oxidation may have occurred in parts of the lode before it was mined, or it may have been developed by subsequent contact with the air in its passage to the mill or during treatment. The lime serves in this way to protect the cyanide of potassium or sodium, as the case may be. In slaking, the calcium oxide (CaO) takes up water to form the hydroxide ($Ca(OH)_2$), which dissolves in water to the extent of one part in 800. Lime is preferable to caustic soda,

[7] Sodium cyanide is used, but all calculations are made in terms of the equivalent potassium cyanide. 100 lb. NaCy is equal to 128 lb. KCy, therefore in practice eight-tenths of NaCy does the work of one unit of KCy. The chemical action is the same, the lesser freight on the more concentrated form of the cyanide making the sodium preferable to the potassium salt.

for this particular purpose, because the calcium carbonate is insoluble in water, while the sulphate is but slightly soluble, so that they do not accumulate in the cyanide solution, as is the case with the corresponding sodium salts where NaOH is used as the neutralizing agent. Soluble carbonates are also precipitated by it, leaving caustic alkali in solution, thus:

$$CO_2 + Ca(OH)_2 = CaCO_3 + H_2O$$
$$Na_2CO_3 + Ca(OH)_2 = CaCO_3 + 2NaOH.$$

By reason of its physical function in the mill, lime coagulates slime, so as to cause settling of the particles. The effect is complex. Much of the material classed as slime is of a colloid nature; indeed, slime has been recently labeled a 'colloid hydrate.' Such matter when brought into contact with pure water becomes almost gelatinous, and therefore impervious to solution. There are several substances, notably alum, acids, soap, and lime, that, when added to the turbid water, cause the gelatinous matter to coagulate or flocculate, so as to produce a separation into distinct agglomerations. Further, minute particles of ore, whether slimy or not, if suspended in water and refusing to settle, develop a tendency to subside when lime, alum, and other substances are introduced. Although imperfectly understood, these reactions are used largely both in metallurgy and in agriculture.

The slime settles rapidly; within two minutes there is an inch of clear water. Then the clear solution is decanted and passes to a filter-vat, the bottom of which is provided with two or three feet of sand

on the top of burlap. This removes any remaining trace of slime, cleaning the solution so that it is fit to go to the precipitation-house.

Returning to the treatment-vat; the slime remaining after decantation undergoes further agitation. The vat is filled with a 0.03% solution and agitation ensues for 1½ hours. Then follow three more successive washes. The vat is then filled for the fifth time and the mixture is thrown by a centrifugal pump into a deep settling-vat. Five of the treatment-charges go to one of these vats, of which there are six, each being 20 feet deep and 34 feet in diameter, with a capacity of 450 tons. The successive charges from the treatment-vat are fed into one settling-vat until it is full of slime, for as fast as the solution gathers on top it is run off, just sufficient time being given for clarification. This clarified solution is so poor in gold and silver that precipitation is not attempted, the solution being used as the first of the washes in the treatment-vat.

The new mill contains three tube-mills. All of them were made by Krupp, at Essen. The No. 3 mill is 19 ft. 8 in. long with 3 ft. 11 in. diameter; No. 4 is 4 ft. 11 in. diameter, and 23 ft. 9 in. long, while No. 5 is of the same diameter as the last, but 26 ft. 3 in. long. The smallest of the tubes is found to do most work per horse-power required. In Western Australia the tubes or grit-mills (as they are often called) have been cut down to a length of 13 feet, but the ore at Kalgoorlie is softer, so that grinding is more

quickly accomplished than at El Oro. The time required is determined directly by the hardness of the rock, for the ore is fed at the upper end and makes its exit at the lower, through a screen. Of the three types of tube-mill, the Abbé can be filled more than half full; this cannot be done with the Krupp mill because it both fills and discharges at the centre. The Davidsen has central feed but peripheral discharge, while in the Abbé mill this is reversed, the feed being peripheral and the discharge central. The last mentioned is built in divisions and the driving is done on tires and by gears, which circle the exterior of the shell, like a Bruckner furnace. The Krupp tube is made of wrought-iron sheets, welded; it runs on trunnions placed at one end, so that the shell does not come into play as regards the driving of the machine.

The lining of tube-mills is an important matter. Chilled cast iron, both that imported from Krupp's works and that made by the El Oro company itself, has been tried; the latter costing one half the former and giving equal wear weight-for-weight. Krupp's lining is from 7/8 to 1 inch thick; El Oro lining is 1 1/8-inch thick. Nevertheless, it is the intention of the manager[8] to substitute silex, a natural flint with characteristic conchoidal fracture; it is whittled into shape in Germany before shipment, arriving in pieces 2 1/2 to 4 in. thick, 4 in. wide, and 6 in. long. The peb-

[8] Robert M. Raymond, to whom I am indebted for much valuable information, and for a personal kindness it is not possible adequately to acknowledge.

bles that do the grinding come from the coast of Denmark. They vary in size from that of an egg to that of a fist, the average being about three inches in diameter. They wear well, six pounds of pebble being abraded during the grinding of one ton of sand; the consumption of lining being 1.6 pounds. [Since then the abrasion has been decreased to one pound per ton of sand.] An attempt is being made to select some of the flinty quartz, such as occurs in the low-grade ore of the mine, to serve as grinding material. This seems wise; if the hard portions of the ore can be used to grind the soft, the economy is obvious. [According to later advices, this was not a success. I also learn that the lining of silex has been discarded in favor of bar plates.]

At the time of my visit, No. 3 tube was being driven at the rate of 31 revolutions per minute, while No. 4 and No. 5 made 29 revolutions. The duty of the individual tube-mills cannot be stated; 172 tons of the coarsest sand from the new 100-stamp mill is re-ground from 35 mesh to 150 mesh, or finer, by the three tubes. In addition, 85 tons per day of the coarsest of the 40-mesh sand coming from the old 100-stamp mill is reduced to the same condition, making the total work of the three tubes 257 tons.

The tube-mills get everything above 150 mesh, as separated by classification in cones. The aim is to grind to 150 mesh and this is accomplished as nearly as the capacity of the plant will permit. Any oversize is returned—as already described—to be

re-ground. The cyanide treatment is based on making a product of sand as nearly 150 mesh as possible, while the 200-mesh pulp and finer are treated as slime. This tube-mill practice has steadily gained in importance, the tendency being to treat a larger proportion of the product from the stamps and to augment their crushing capacity, while enlarging the cyanide annex. This is a proper way of meeting the necessities of a mine the output of which increases in tonnage as the assay-value declines.

The following statement of the work done during the month previous to my visit explains itself:

REPORT OF CYANIDE DEPARTMENT, SEPTEMBER, 1905.

MILL No. 1.

		Gold		Silver	
Classification.	Tons treated.	Assay-value per ton.	Indicated extraction.	Assay-value per ton.	Indicated extraction.
%		$	%	$	%
Coarse Sand ...29.23	2,552	9.46	54.33	1.73	27.17
Fine Sand 25.57	2,233	7.86	72.14	1.57	45.86
Slime 45.20	3.947	9.04	93.58	2.03	82.26
Total 100	8,732	8.86	76.50	1.83	58.99

The old mill was built before re-grinding was adopted. The fine sand is poorer than the coarse because it contains less gold open to attack. The slime is richer in silver because of the presence of argentite.

MILL No. 2.

%	Tons.	$	%	$	%
Sand 24.12	2,527	8.28	83.94	1.59	65.41
Slime 75.88	7,949	7.68	92.45	1.64	78.05
Total 100	10,476	7.82	90.28	1.63	75.08

The new mill includes a systematic scheme of re-grinding, as shown by the increased proportion of slime. A better extraction on slime raises the general result to a satisfactory figure.

CYANIDE-VATS AND TAILING-WHEEL

Interior of the El Oro Stamp-Mill

Chapter II

FURTHER NOTES ON EL ORO PRACTICE — THE STAMP-MILL — MORTARS AND GUIDES — APPARATUS FOR SIZING — THE PRECIPITATION HOUSE — FILTER-PRESSES — RECORD OF TESTS.

A FEW scattered notes on the El Oro mill may be worth recording. The bolts of the battery-frames are coupled by washers; these are 6 to 10 inches long and from 2½ to 3 inches wide; they connect two bolts and hold them firm. If one gets loose, the other holds it in grip and prevents movement. The accompanying photograph* of the interior of the mill will aid the description.

The guides are made at the company's foundry, of cast iron; instead of being sectional, with bolts, they consist of one solid piece. Each stamp has its own guide and a right-angle plate, to keep it in proper place and line. The wear is slight and therefore the stamp works smoothly; there is less heating than with wooden guides.

The mortar is a development of the anvil-block. This is an excellent mode of construction, if properly done. I know of one case—not in Mexico—where

* For many of my photographs of El Oro I am indebted to Mr. Alexander Anderson.

trouble was caused by the anvil-block being constructed so that it did not rest perfectly true on the cement foundation; to remedy this, it was the custom to shim the concrete block with a little cement; when this last broke and crumbled, there was a movement of the mortar itself. At El Oro, the mortar-block is made extra heavy, becoming to some extent an anvil in itself, with a base three feet wide and a bottom 13 inches thick; this is placed upon a concrete foundation, with a piece of quarter-inch rubber belt between.

At El Oro, cones are superior to spitzkasten; the sizing tests have proved this abundantly, the separation by the cones being much sharper. The circulation and agitation of slime are aided by six pumps, which are the Butters modification of the Gwynne pump, such as is used in the London dockyards. They are of the centrifugal type; compressed air is introduced to effect aeration of the solution. The chief advantage of the Butters modification is that all wearing parts are readily removable. Each pump makes 1,300 revolutions per minute and in that period handles 4½ tons (3½ tons being solution) of slime.

The vats are all made of steel plates, $\frac{5}{16}$ inch thick on the sides, with ¼-inch bottoms. Redwood laid down at El Oro comes to the same cost, but the steel is more durable and makes a tighter vat in a climate such as that of central Mexico. The vat does not dry if empty, there are no staves to check, and there is no absorption of solution.

In the precipitation-house, there is used a device introduced independently by W. K. Betty in South Africa and by Alfred F. Main at El Oro;* I refer to a drop-drip of cyanide (2½% solution) over the head compartment of each zinc-box that is precipitating from the weakest solution, namely, the one coming from the treatment of slime. This drip makes the zinc more active, so that a precipitation of precious metal is obtained in a manner usually unattainable from so weak a solution, that is, one containing only 0.02% KCy. Still weaker solutions are successfully precipitated in which the quantity of cyanide is so small as not to be detected by the ordinary silver nitrate test.

The method of dipping the zinc shaving in lead acetate (to aid precipitation) is not employed at El Oro because lead acetate is used at another stage of the process, as already explained. Zinc fume was tried, but it was ineffective with such weak solutions. Great care is taken with the zinc shaving, to cut it in thin but tough filaments, not so crinkly as to break easily in handling. The shaving is laid in the boxes most carefully, so as to avoid channeling. The El Oro plant is the only one of its size where acid treatment is not used. From the boxes the zinc is sent through launders, to be carefully screened, while it is also being washed with fresh water. Then it is pumped into two filter-presses until they are full, the

* Mr. Main is assistant manager for the El Oro Mining & Railway Company.

charge being equivalent to 19,000 ounces of bullion. The effluent solution is returned to the sump, the cakes in the press are washed and then dried by steam, the steam heating the iron of the frame sufficiently to dry the cake inside. The cakes are dried to such a consistence as will facilitate fluxing before briquetting; they fall into a car and are then mixed with the fluxes needed for melting; the mixture is fed into a briquetting machine, making round bricks 3½ inches thick, 3 inches in diameter. These are dried before being thrown into the melting pot, from which bars of 1,000 ounces are cast. The Mexican workmen are compelled to remove their clothes after work, before passing to the outer room. The precipitation-room has a cement floor and the furnace has a dust-chamber.

The development of milling at El Oro emphasizes the relative importance of the cyanide annex in the modern wet treatment of precious-metal ore; the annex to the new mill required an expenditure a little more than twice the cost of the new 100-stamp mill itself. The tendency is to increase the percentage that is re-ground, the perfection of the extraction being largely dependent upon the fineness of comminution. At the time of my visit the aim was to make two products; sand, as near 150 mesh as possible (and a decreasing percentage even of that) and slime, that is, all below 200 mesh. Of course, sand, even when re-ground, is different from clay, despite equality in size of particles; the grains

of 'sand' are sharp as against those of a mud (slime) rendered impalpable by absence of sharp edges. 'Sand,' however fine, filters well, while 'slime' will not filter at all; it packs like glue. On the other hand, by reason of the relatively larger surface presented by minute particles, chemical action on the precious metals in 'slime' is almost instantaneous. How necessary re-grinding is, was shown by a simple experiment made by Mr. S. H. Pearce. Sand, after ordinary cyanide treatment at the old mill, where there is no re-grinding, was dissolved in *aqua regia*, but the 'purple of Cassius' test, with stannous chloride, gave no precipitate whatever, the gold being effectively locked within the grains of quartz. The assay of the sand gave $4.50 per ton. Hence the need for re-grinding.

The accompanying record of tests will prove interesting to those engaged in cyanide work. Looking at Fig. 8, it will be noted that the legend explains the graphic representation of two sizing tests. At the time of these tests, a 2½-inch chuck-block was used, but it was too low to have much effect on the degree of fineness of the product; during the test the stamp-discharge was as through 28 mesh. Under these conditions the load on the tube-mills and on the plant became too heavy, so that finer screens were substituted shortly afterward. In the diagram (taken from the paper by Caetani and Burt, already mentioned) the ordinates represent the size of the screen and the abscissæ the percentage retained on each of

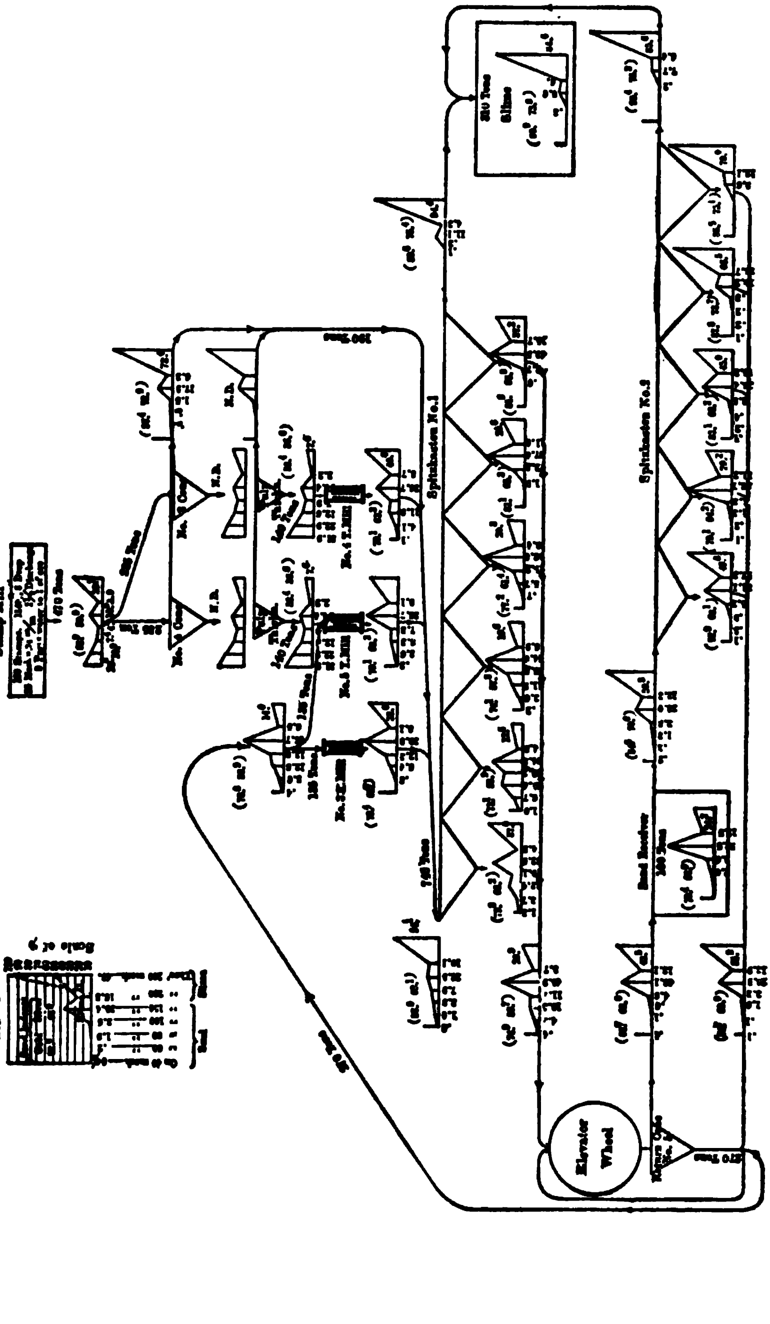

FIG. 8. DIAGRAM OF SIZING TESTS AT MILL NO. 2. (SEPTEMBER 1, 1905.)

the screens. In the legend, "Thro' 250 mesh" should read "through 200 mesh."

The use of the term 'sand-index,' to be seen in the note appearing on the diagram, requires explanation. Caetani and Burt employ it, and it represents one of the most valuable features of their paper. The problem may be stated thus: Given two sands of the following analysis:

Mesh	On 20 %	On 40 %	On 100 %	On 200 %	Through 200 or slime
1st sand	10	30	25	5	30
2nd sand	5	15	45	15	20

Which of these two sands is the finer? Caetani answers the question from the economic point of view, thus[10]: It is desired to know the fineness of a sand for the reason that the finer the sand, the better the extraction obtained. Therefore the maximum possible extraction on a sand of given composition *is a number proportional to its fineness, considered from an economic standpoint.* As at El Oro the metallurgist can *a priori* calculate exactly the extraction from a sand when a sizing test has been made, therefore he can calculate the index and represent thereby with *one* number what would otherwise have to be indicated by a tabulation consisting of 14 numbers. In the examples quoted at the beginning of the paragraph, the second sand is finer than the first, although it contains less slime.

[10] In a letter to the author.

Chapter 12

THE MILL OF THE ESPERANZA — USE OF HUNTINGTON MILLS — TREATMENT OF SAND — NO AMALGAMATION — EXTRACTION.

THE Esperanza mill had 120 stamps when the present company took it over, in 1904. It was deemed advisable to increase the capacity at the least possible cost, so 15 Huntington mills (each of 5-ft. diam.) were added, with the idea of re-grinding before cyanidation. This was tried, but it was found necessary to place the Huntingtons above the stamp-batteries, which necessitated elevating the pulp. It being difficult, therefore, to distribute the pulp to the Huntington mills, it was finally decided to use the latter machines for first grinding, in association with, instead of in succession to, the stamps.

The crude ore passes over a 1½-inch grizzly before it reaches the rock-breakers; after being crushed by them, the ore goes over a ¾-inch grizzly, the undersize being allotted to the Huntingtons and the oversize to the stamps. The batteries are provided with 60-mesh screens; while the pulp issuing from the Huntington mills goes through an angle-slot screen

Leaching-Vats of the El Oro Mill

Blaisdell Excavator and Sand-Vats

equivalent to 60 mesh, only 65 per cent of the product will pass 200 mesh.

Of the 15 Huntingtons, 6 are now used as first grinders on low-grade sulphide ore, the product being sized and distributed to 6 Wilfley tables, the tailing from which, after classification, passes down blanket-sluices before finally reaching the cyanide-vats. The concentrate from the Wilfleys and that washed from the blankets, goes to the smelter at Aguascalientes.

The other nine Huntingtons treat oxidized ore, which, after being ground, goes to the cyanide annex. The cost of steel and repairs to wearing parts amounts to 34 centavos per ton; labor averages 15 to 20cv. per ton. The muller-shells and die-rings are made of rolled steel manufactured by the Midvale Steel Co., of Philadelphia. This is a soft metal and is susceptible of being kept to shape; it can be used until worn out, and is, therefore, economical. Each Huntington mill has its own motor; it has proved itself to be the best machine for reducing the ore to a certain point —say, 60 mesh—beyond which, for finer grinding, it is not economical.

The sand undergoes treatment for 100 hours; for it is found that extraction ceases then. Aeration is effected by a perforated pipe discharging over the return-solution vat; yet there is no such loss of cyanide as might have been expected. The former collecting-vats are now used for treatment; there is less aeration and less mixing, but there is a great gain in

the capacity of the plant without interference with effective percolation. A vacuum-pump, for withdrawing the enriched solution, is used only at the close of the operation. Sodium cyanide, NaCy, is the chemical employed; it is guaranteed equal to 125% active KCy, ranging from 124 to 128 per cent. The enriched solution, before precipitation in zinc-boxes, is rarely higher than $2.20 in gold. Fresh cyanide, in crystals, is added to the head of the zinc-boxes, sometimes in quantity sufficient to keep the solution up to standard strength.

There are no amalgamating plates, and no mercury is used in the Esperanza plant. This is an interesting divergence from El Oro practice.

During September, 1905, the output of the mine consisted of 5,280 tons of shipping ore and 12,000 tons of milling ore, having together a value of $780,385. The extraction in the mill was 91.64 per cent of the gold and 52.92 per cent of the silver in the crude ore.

At this time the Esperanza was the most productive gold mine in the world, the two ranking next being the Simmer & Jack, with a monthly output of $505,000, and the Robinson, with $450,000; these two mines being in the Transvaal.

Chapter 13

MINING METHODS IN THE EL ORO MINE—DIAMOND-DRILLING IN THE ESPERANZA—TIMBERING BAD GROUND—PRECAUTIONS TAKEN—LAYING OF TRACK—EXCELLENT SYSTEM.

NO time is wasted in handling ore from the El Oro mine. At the main (incline) shaft there are two gyratory (Comet D) crushers, the oversize from which goes to a jaw (Reliance) breaker, 9 by 15 inches. Thence the ore passes into bins and from them it is fed onto a (Robins) belt-conveyor, which is made in divisions as demanded by the length (about 200 yards) and the slope to the mill. At the mill the ore is delivered by the conveyor to a traveling tripper which distributes it automatically into the bins; the tripper moves over the bins the entire length of the mill and then returns.

When opening up ground previous to stoping, it is the custom to run a main drift in the middle of the hanging-wall orebody, leaving ore on both sides up to the top of the timbers constituting the drift-set. Then stoping begins above the drift for the full width of the orebody. When the ground begins to weaken and re-timbering has been carried as far as practic-

able, the stopes will be about half-way up to the next level; then the drift in the foot-wall orebody is utilized, by driving cross-cuts from it to the hanging. These tap chutes wherever practicable, but if the ground near a chute has caved, then a new raise (from the lateral drift) is made to serve the purpose of extracting ore. Finally, when even the foot-wall begins to be bad, a lateral drift is run in the foot-wall country itself, and this sometimes leads to unsuspected occurrences of ore.

Another procedure is to leave about twenty feet of ore above the top of the hanging-wall drift; the arch of ground being removed upon the final extraction of that block of ore. This method is employed when the maintenance of a roadway is vital, especially when approaching a shaft.

It is instructive to note that while the operating expenses at the Esperanza during 1904 represented 74 per cent of the production, after the bonanza was struck the proportion of expenses decreased to 37 per cent. The diamond-drill cut the new West vein in August, 1904, and the discovery was mentioned by Mr. R. T. Bayliss at the El Oro annual meeting in October, 1904, but the big rise in Esperanza shares did not begin until the spring of 1905. The story of the discovery illustrates anew how deceptive a single cross-cut can be. The West vein was cut by a cross-cut on the third level at a point 150 feet north of the south boundary of the mine; the ore was poor, about 15 inches of stuff assaying 17 grams of gold per ton.

Next it was intersected in a drill-hole 900 feet north of the place just described, but on the fourth level. Here also it was poor, about 18 inches, assaying 12 grams. This was done by the former Mexican company about four years before the eventual ascertainment of its real value. In August, 1904, the drill-hole put out by the new management, at the fifth level, cut the northern portion of the orebody and found 22 feet of an average value of $37 per ton. But the cross-cut which was started at once on the track of the hole cut an 11-ft. vein assaying $75, the probable explanation being that the drill followed a cross-stringer connecting a poor vein, 5 feet thick, to the 11 feet of rich ore, there being 6 feet of shale between them, so that the 22 feet of core assayed $37 per ton.

The discovery is creditable to the management, as it was owing to their good judgment in the use of the drill. Now two drills are kept in constant use, although this manner of testing the ground is expensive, because the hard quartz abrades the carbons. The average cost is five pesos per foot of ⅞-inch core. A Sullivan E drill is used, capable of drilling 400 feet.

In the Esperanza mine, it is the custom to extend main drifts in the ore, which is hard and stands well. Although the shale is softer, it is found economical to keep within the vein, because this practice obviates timbering as the drift progresses. When the drift has been advanced the desired length—a month's or even two months' work, at 65 to 70 feet per month—the ore is taken down on both sides and

double drift-sets are put in place. When mining near the big fault, skillful work is required. On the upper levels the shattered ground is narrow, but this evidence of faulting increases in depth, so that while it is barely one foot wide on the first level, it is 20 feet

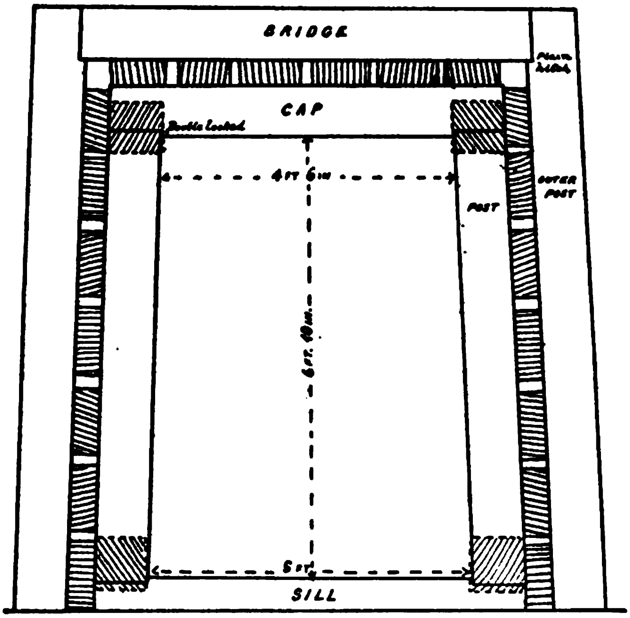

FIG. 9.

wide at the fifth, where it is dangerous. In order to traverse this ground, not only is 'spiling' required on top, but also on the side of the drift. The set is put in place in the customary manner, with cap, blocking, and 'bridge,' so that it looks like Fig. 9. The 'bridge' serves as a resting place

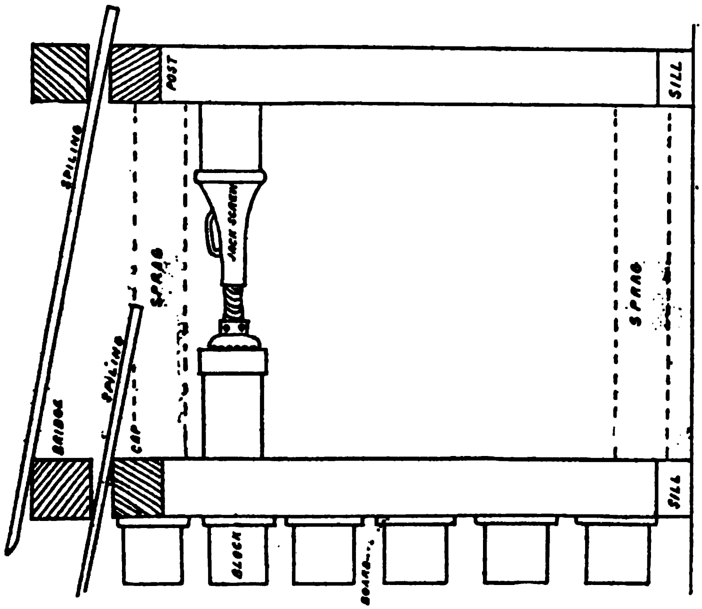
SPILING
POST
SILL
JACK SCREW
SPRAG
SPILING
BRIDGE
CAP
SPRAG
SILL
BLOCK
BOARD

Fig. 11.

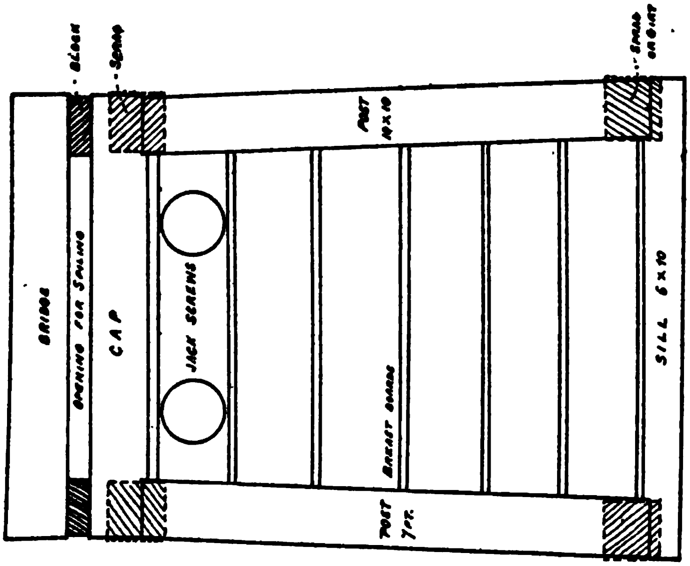
BLOCK
SPRAG
SPRAG
BRIDGE
OPENING FOR SPILING
CAP
JACK SCREWS
POST
10 x 10
BREAST BOARDS
SILL 6 x 10
POST
7 FT.

Fig. 10.

for the spiling poles and allows space underneath for driving. Pointing the spiling upward and sharpening it from one side, tends to lift the soft rock. When the spiling has been pushed on top and at sides, it is driven either with a sledge-hammer or, if that is ineffective, with a ram. If the roof-spiling needs this treatment, the ram is put on rollers. This ram is a piece of 8 by 8 inch timber, from 8 to 10 feet long, so as to get a good run with it over rollers; if it is to be used for driving spiling near the floor, the ram is suspended from a roof-timber and thus it gets a swing. If the ground commences to run, the face is bulk-headed with 4 by 12 or 6 by 12 inch planks, according to conditions. These breast-boards are then blocked by spiling, both on top and sides. The next step is to advance them. If the bottom one is advanced first, the ground would run, but if the top one is pushed, there is nothing to escape, because the top spiling holds it back. Therefore, two jack-screws are brought to the spot and they are placed with heel (or base) on a cross-timber carried by the rear set. The top breast-board is now advanced 8 or 12 inches and a sawed-off block is inserted within the space thus obtained; this block holds the breast-board in its advanced position. The next board is pushed to a corresponding position, as before; the cavity made is cleared, the soft ground being taken out over the top of the next lower board. This procedure is repeated with the other boards until they are all in line, marking a permanent

advance of 8 or 10 inches or more, as circumstances permit. This is position No. 2, as shown in Fig. 10. On the next advance, longer blocks are used to keep the breast-boards in place and the work goes on until room has been made for another set. See Fig. 11.

The north shaft is sunk through bad ground, particularly a length of 200 feet between the third and fourth levels, and another stretch from the eighth to the ninth. There is a creep of 15 inches per an-

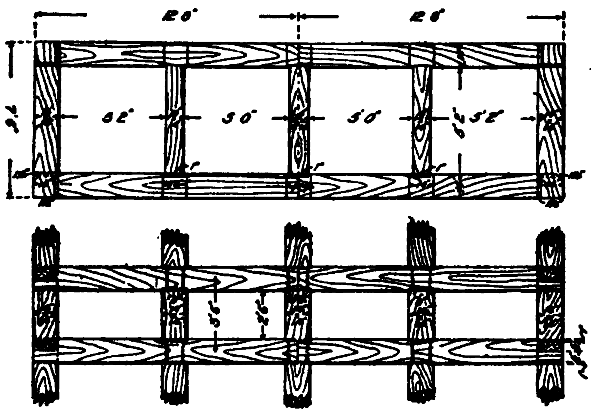

FIG. 12. SPECIAL SHAFT SET; 14-IN. TIMBERS.

num, and it is found necessary to renew the timbering every nine months; this is done by a gang of *peones* specially trained under a Piedmontese foreman. See Fig. 12.

Double sets are used for timbering main drifts; all the caps are double-locked to prevent splitting and, in rare cases, even the sills are double, when the ground underfoot tends to rise. In such cases an

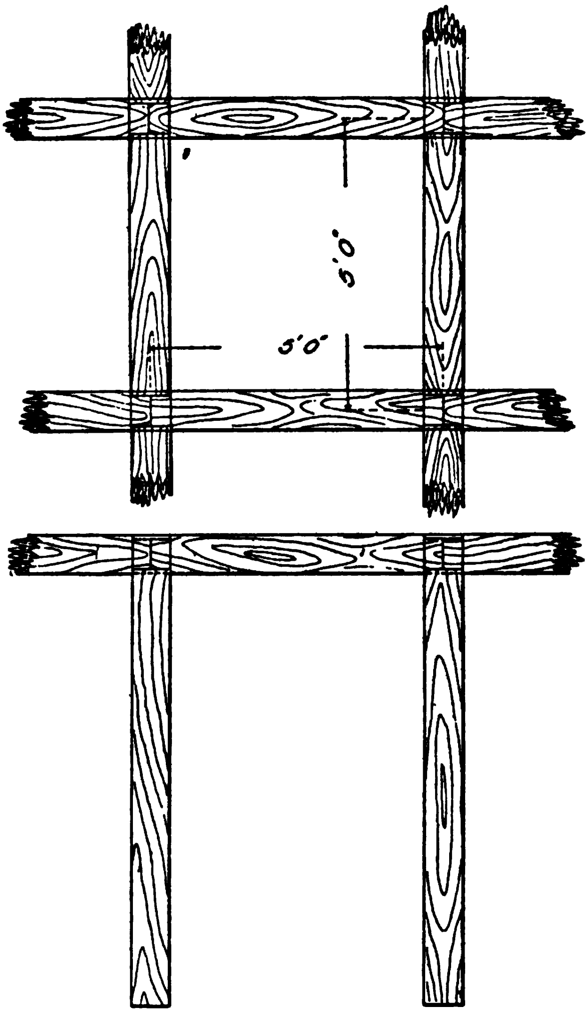

FIG. 13. SQUARE SET. 8-IN. TIMBERS. PLAN AND ELEVATION.

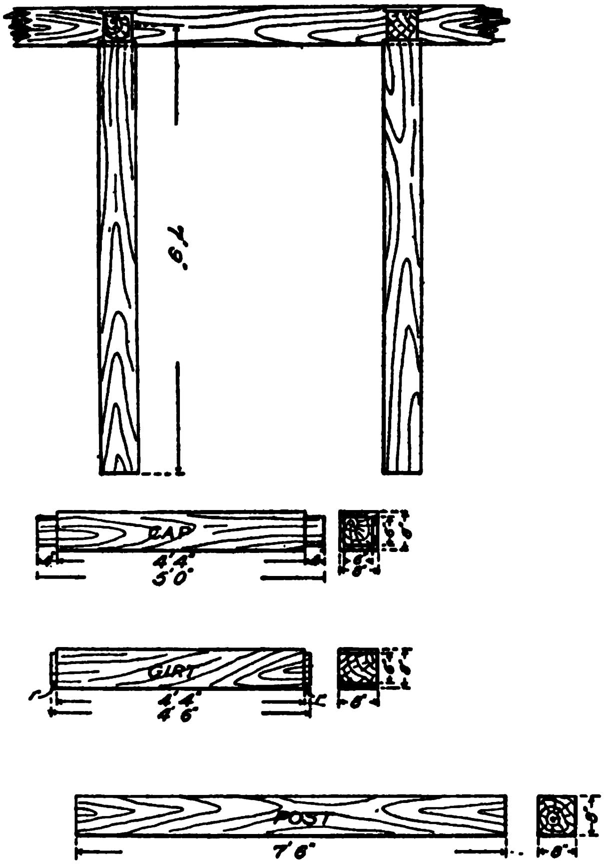

Fig. 14. Square Set. 8-In. Timbers. Side Elevation and Details.

intervening block of ten inches is inserted, the bottom sill being the first to break. Ordinary sets would last only 60 days, the double sets are in service for 12 months; the top set takes the weight and yields, without interfering with the use of the drift. The lower set remains unimpaired, until finally it is pushed too hard; then the pressure is opposed by the erection of a false set, which, while the lower set is being replaced, does service as a top set.

In bad ground it is the custom to leave from three to four inches between the lagging, so as to permit the soft ground to come through, but not enough to block the tram-track. After this the ground is not eased further until the lagging breaks; it is then replaced by fresh poles. If the weight is from overhead, no effort is made to ease the pressure, which is allowed to break the timbers, to be replaced by fresh sets. The choice is between losing time in cleaning the track or letting the timber stand as long as possible before renewal. It is held that the question of blocking the track is paramount in a mine producing so large a tonnage of rich ore.

Where it is the intention to encourage the ground to get relief of pressure by pushing through the lagging, the space between poles is six inches. Close lagging requires more frequent renewal, but it eases the timbers. By allowing the side of the drift to break through, more weight is thrown on the timbers, by the enlargement of the arch of ground overhead.

Stope-sets are five feet from centre to centre,

with a height of eight feet. They are so placed as to oppose the tendency of the walls to close, and the consequent strains are all accepted on the end of timbers. See Fig. 13 and 14.

Great care is taken with the tracks and admirable system is exhibited in the arrangement of them. The cars weigh 1,100 pounds each and carry 2,200 pounds, the total weight being 3,300 pounds. The gradient is a half of one per cent, that is, it is such that the labor of pushing an empty car up-grade is approximately equal to that of pushing a full car down-grade. The width of track is 23 inches, or 60 centimetres, the gauge being based on the metric system. The rails are 20 pounds per yard, and of Carnegie cross-section. The minimum curvature adopted throughout the mine is a 12-ft. radius, for which standard cast-iron right and left-handed frogs are used. Switch-points are carefully made in the Esperanza company's own shops; the points themselves being reduced in a planer instead of the customary blacksmith shop. All of these precautions tend to assure easy handling of heavy cars by inferior native labor. Special tools are provided for bending and punching the rails; all curves are laid to template. The ties are 2 to 2½ feet apart and are made of 6 by 8-inch timbers. On curves the gauge is widened 1½ inches, and the inside of curves is protected by a guard-rail; the same protection is provided at the points of all frogs. When using hand-cars, fixed points are laid down; but where electric

FIG. 15. SPLIT SWITCH, FOR ELECTRIC MOTOR UNDERGROUND.

motors run, the switches are made movable. See Fig. 15 and 16.

The Esperanza company maintains elaborate assay-plans. There is one for each floor in the stopes, the floors being 7½ feet apart. On the plan the timber sets are marked in 5-foot squares; each month's work is indicated by a different color, and in every set the assay-value of each square of ground is marked in figures indicating grams of gold per metric ton. There is no assay for silver because the ratio between the metals is known from experience; in oxidized ore it is 6½ grams of silver to 1 gram of gold; in sulphide ore the proportion is as 15 to 1. Every car loaded with ore from a chute is grab-sampled at the shaft-station, the assays thus obtained giving the average value of the mine-output for that day, while the number of cars gives the quantity. Thus 350 mine-assays are made per diem, and these also enable the foreman to keep a check on the kind of ore being broken. Gangs of samplers, in pairs, test daily each working face in stopes and drifts; a sampler within the space of one set will get a chance to test more than one face, sometimes three of them. Both the moil and the pick are used; the ore is broken onto canvas spread underneath; the samples average 50 pounds apiece and are quartered down to 5 pounds each, before they go to the sampling-room at the assay-office. All these returns are compared with the battery sample from the mill.

El Oro GENERAL VIEW OF EL ORO Esperanza, Mexico

The Esperanza Mine and Mill. To the Extreme Right Is the Mexico Mine

Chapter 14

TAXES — THE DYNAMITE IMPOSITION — ELECTRIC POWER — DOS ESTRELLAS — ITS DISCOVERY — THE HUMOR OF CYANIDING — HOW BOUNDARY MARKS ARE PRESERVED.

TAXES are heavy at El Oro. They amount, for instance, to 13 per cent on the gross output of the Esperanza mine, but this includes State and Federal taxes, import duties, and the care of troops stationed in the district. On bullion the mine pays 2½ per cent to the Federal Government and 1½ per cent to the State.[11] All State taxes are subject to a second imposition of 25 per cent, which goes to the Federal department. There is a wage tax, so much for each man on the payroll; there is a stamp-tax on every recorded business transaction; and there are duties on imports, particularly on dynamite.

On dynamite there is a tax of 243 pesos per ton. The El Oro mine uses 185 cases, of 50 pounds each, per month. The Esperanza mine consumes 400 cases, or a carload in six weeks, so that the tax weighs heavily. It is intended to compel the mining

[11] Gold, however, is now being purchased by the Government, and on bullion parted and refined in the country the Federal tax on gold has been removed, while the silver tax is reduced to 1½ per cent.

companies to use the domestic dynamite; but the Mexican company's factory was blown up twice and they had ceased to manufacture at the time of my visit; nevertheless, according to the terms made with the Government, they had to furnish 60% dynamite at 19.34 pesos per case of 50 pounds—a rate fixed by the Government, as against 16.34 pesos, the old price. While the factory was in operation it cost 29.67 pesos to import the explosive from the United States; the company (Mexican National Dynamite Co.) was furnishing (in October, 1905) American dynamite for 19.34 pesos, but as soon as their factory resumed, it was expected that they would sell their own product at the same price. Americans mining in Mexico consider it to be unsafe and usually prefer to import dynamite at 29.67 pesos. Recently, one of the leading companies at El Oro has made arrangements to buy from the monopoly, which furnishes American dynamite at about the same price as paid formerly. The management could not import the American powder direct, however, without paying the increased price. The monopoly is allowed to charge 16.79 pesos for 40%; 18.07 for 50%; and 19.34 for 60% dynamite.

The electric power used at El Oro comes from the Necaxa plant, on the river of that name, 176 miles distant. At the time of my visit the line was nearly completed. It has been built by Canadian capital. Mexico City is supplied from the same power-plant, the distance being 100 miles from the falls to the city

and 76 miles from there to El Oro, over the wires. There are eight circuits of three wires each between Mexico and Necaxa, and two circuits, also of three wires, from the city to the mines. Fifty thousand volts are delivered at El Oro, by a three-phase system, and it is expected that there will be a loss of eight per cent as far as the city and an equal loss thence to the mines. The current does not go through a transformer at Mexico. Power is generated under a head of 1,450 feet by a vertical-shaft turbine with the generator on top; the wheel is the invention of Escher Weiss, at Zurich (Switzerland). The hydrostatic head at Necaxa has been obtained by the building of an earth dam, 185 feet high, 1,500 feet thick at the base, and three-fourths of a mile long; it holds 55,000,000 cubic metres of water and backs the river 2¾ miles. The transmission cable has a jute core and consists of six strands of No. 6 wire equivalent to No. 000 wire or 0.229 inch. The power is sold to the mining companies on a sliding scale, the prices being graded according to the amount consumed, the lowest price being $50 per horse-power per annum to those consuming over 1,000 horse-power. Several times the natives have cut down the wires and stolen them, on two occasions as much as a kilometre being removed. This has been exaggerated by rumor to seven or eight kilometres. As soon as the cables were erected, a small current (generated by a steam-plant at Mexico City) was put on, in order to prevent stealing; the result was that

several *peones* were killed. Later, when one line had a current and the other not, the thieves seemed to know enough to distinguish between the dead line and the live one. The copper stolen is cut up and sold to the junk shops.

Dos Estrellas, or the Two Stars, is one of the three great mines of El Oro; it is interesting not only because of its generous production but also by reason of the romance of its discovery. J. G. Fournier, its present chief owner, is a Frenchman of education who prospected the surrounding region with much persistence. He found 'float' (detached lode-stuff) where the shale is exposed below the andesite cap and he found similar indications also in the *barranca* (or gulch) at the foot of the mountain. Subsequently, he started to work at the creek-level and ran a long adit to intercept the vein that he believed to be there. At a distance within the mountain of about 2,000 feet he found it, and no mistake. It was the great Dos Estrellas lode, which is divided into two veins, one 3 to 5 feet thick, with rich bodies of ore in it, and beyond it another vein 40 feet thick of 12 dwt. gold ore; the latter is oxidized, but the small vein is not, except in patches. This resembles the conditions in the Esperanza, where the new West vein is smaller, richer, and unoxidized, while the old San Rafael is wide, poor, and thoroughly oxidized. Fournier was long ago regarded as a crazy man, as has been the case in several similar instances of persistent prospecting. Thomas Kruse, who discovered the Drum-

lummon lode, at Marysville, in Montana, worked all alone. He started to sink a winze and gave it up; he then commenced to dig a 'tunnel' for a supposedly unknown lode. When he cut a big width of ore, it was considered, by the ignorant, as 'fool luck.' But it was nothing of the kind; old Tommy Kruse had found an outcrop and he knew that he alone could not sink a shaft, but he could drive a drift into the hill without assistance and without the risk of sharing in the proceeds of his discovery. He persisted in his solitary labors, and won a fortune.

Even the operation of a cyanide plant may yield humorous incidents. A note-book belonging to one of the former assistants was found; it recorded the work done on the night shift in the precipitation-room. The particular fragment rescued from fire contained instructions how to pump out the precipitate-sump and to make cake in the press. The operator, a new hand, had recorded that at a certain hour: "Pump laboring—opened press to see why—found press choked with greasy black substance—removed same—pump worked perfectly." He threw the precipitate into the old (empty) cyanide-boxes, where it was found next day; no damage was done. Another story is that of visitors being shown over the new mill by a guide from the village of El Oro; he pointed to the tailing-wheel, which is 40 ft. 8 in. high, and said that it was the wheel that operated the mill, the conveyors, and everything in sight. This wheel is run by wire-ropes; there are two that transmit

movement to the wheel itself, there are four that drive the first line of agitator-shafts, and there are two more that go to the pumps; all of them happen to be close together and doubtless the number of ropes created the idea that the wheel was responsible for a great multiplicity of duties.

The only salvation for land titles is due to the regulation that compels monuments to be visible from one to the other. By law also it is specified that the monuments must be permanent stone structures; otherwise there would be hopeless confusion, for the records in the mineral-land offices would be unintelligible, because there is no general map and the boundaries of claims are not referred to any fixed point or landmark.

The boundaries between the Esperanza and El Oro mines are marked by posts of masonry plastered with white mortar; they are set at each corner of a claim and where the lines are long they are placed at such intervals as to be within sight from one to the other. The natives of the vicinity, who thought they had a squatter's rights to the ground, started to demolish these monuments, until the company's surveyor marked, with black paint, a cross on each one; since then they have been reverently left untouched. Similar superstitious feeling is seen in other observances. Wherever a man dies—whether naturally or not—a cross is set up, even underground in the mine; and each man who passes by picks up a stone, which is supposed to represent a paper, the equivalent of a

THE WATER-CARRIER OR BOTERO

The Cross near the Somera Shaft

Pay-Day at the Casa Blanca, El Oro

prayer, and drops it at the place so designated. On the day of the Holy Cross every cross in the country is decorated with flowers, even artificial ones if others are not procurable. By the heaping of stones at such spots, a cairn is eventually formed, serving as a landmark. At the place where a priest was killed, near the Somera shaft, there is an enormous pile of stones, as is shown by the accompanying photograph.

In the course of a ride on horseback over the surrounding district, on a Sunday, I observed something of the life of the people. There is a notable absence of vehicular traffic; there are no ruts in the roads, which practically are causeways, worn smooth by the sandals and bare feet of the peasants. The paths look as if all the 'weary Willies' in the world had passed that way. The beauty of the scenery and the picturesque coloring of the people is spoilt by the evil smells due to the filthy habits of the *peones*. At the close of day, when the tropic darkness comes swiftly and the air is suddenly cooled, the Mexicans stalk about silently muffled in their *serapes* and with covered mouth, in order not to inhale the air. It is a characteristic of the people that they fear the cold air, largely because they are so poorly nourished as to be easily subject to pneumonia. With their wide-brimmed conical hats, the dirty red blanket or the striped *serape* thrown over the shoulder, with thin shanks and stealthy gait, the natives stalk about in the gloaming through the narrow street like the brigands of an *opera bouffe*. There is none of the

breezy swing or the cheerful salutation of the Anglo-Saxon; nor is this a matter for wonder when one gets to know the miserable life, the petty tyranny, and the scant food that is their lot. Cleanliness, good food, and freedom of opportunity make people more cheerful even in a climate less sunny than Mexico.

Nothing that I saw in Mexico seemed so pathetic as the conventional acceptance of class distinctions, especially among the women, the sex usually most eager to ape the dress and habits of those who happen to be more favorably placed than themselves. The lowest class wears blue and brown shawls or *rebosos*, the middle class is distinguished by black *rebosos*, and the upper class sports the more dainty *mantilla* or mantle of lace.

The most vivid impression that I took away from El Oro was that of a Mexican boy controlling the operation of a sand-distributor through a variable-speed motor. The boy's pay was 75 centavos, or 37 cents per day, and he had charge of two Blaisdell excavators and the distributor referred to. It was a picture of mechanical ingenuity overcoming a poor labor supply, for it was not the skill of the boy so much as the perfection of the machine that rendered such economy of operation possible.

Chapter 15

MINE LABOR — THE CONTRACT SYSTEM — NATIVE IMPROVIDENCE AND SKILL — DIFFERENCE OF LOCALITY — POOR HAMMERMEN, BUT WILLING WORKERS — HOT MINES.

MEXICANS take kindly to mechanical labor, such as that of the machine-shop or carpentering. The average native carpenter, who gets from 2 to 4 pesos per day, is as good as the white men of his trade that drift into the country from the north. Timbermen are fairly satisfactory also; they receive two pesos per shift. As a rule, the Mexican is clever with his fingers, as is illustrated in the shaping of statuettes and in weaving. Guadalajara is famous for carved images and Cuernavaca for the manner in which its people mold clay into statuettes and flower-pots. The assay crucibles used in the El Oro mill are made locally; so also are the muffles. The crucibles, sizes F and G, holding two assay-tons, cost only two centavos apiece and give excellent service.

The ordinary unskilled laborer—such as is required for carrying material, for unloading, for stacking cord-wood, or in excavating for foundations—is paid 50 centavos per day, but it is becoming difficult to get men for such low pay. In a new mining camp

or on the farm, the day laborer is paid only 25 centavos, while in the north, near the border, he gets three pesos. This is owing to the proximity of the American labor supply and the competition between the mining companies, the wages tending to equalize despite the international boundary, because both the northern workmen and the Mexicans go across that line, to and fro.

Work underground is done on contract as much as possible; even the trammers and skipmen are employed on this system, prices being set so that the miners earn from 1 to 1.25 pesos per shift. In measuring ground under contract, the unit is a width of two sets (3.4 metres) of timbers, and the pay is so much per metre long for the full height of a set (two metres). Mine contracts are made with each gang of six men or more, the agreement being arranged with the two leaders (one to watch the other); and these hire any additional labor such as is needed for removing rock or tramming. Contracts are measured weekly, on Saturday night. Wages also are paid weekly, the surface laborers on Saturday night and the miners on Sunday morning; this frequency of payment being due to the fact that the *peones* have not enough money to carry them longer than seven days. On Sundays the market is crowded with vendors of corn (maize, from which *tortillas* are made), beans (the *frijoles*), vegetables, and fruit. The Mexicans lay in a week's supply; any money remaining is spent on *pulque*. On Monday they are in a demoralized

state. Owing to these customs the laborers lose two days per week regularly, besides an extra feast-day (*fiesta*) each month. But annoying as these conditions are to an energetic management, they are better than they used to be. Even on local holidays, the *peones* formerly took three days for their celebration, while now one day ordinarily will suffice. But there are still seven or eight *fiestas* in the year when no pretense of working is made, and operations underground cease. Of course, these national characteristics of the Mexican do not affect—at least directly—the American workmen; they are paid monthly, and appear to be not only sober in their habits, but also unusually efficient.

In different parts of Mexico the skill of the miners will vary; at El Oro it is less than at Pachuca. The cost per ton of ore is not much cheaper than if done by skilled white miners. Mexicans are not miners by instinct; as long as they can maul at a face and detach chips of rock, they will hammer it, instead of picking it loose or putting in a shot. They are wretched hammer-men; a Cornishman watching them would be inclined to say that it was a "caution," and the American miner would exclaim that it was a "fright." They do not appear to have any of that body-swing, when the hand slips over the long handle of the hammer; instead of this, they have a tight grip and strike short blows over the shoulder; they will insist in shortening the handles; nor do they use the pick where obviously it would bring down loose

ground, but they worry the rock with short hammer-blows delivered with woodpecker persistence. The heads of their hammers get into a woeful condition and their picks are rarely such as a white man would care to own; in general, they appear to take poor care of their tools. Owing to their inability to swing the hammer freely over the shoulder, they cannot drill an 'upper' and therefore they are not much good in a raise; but they are most expert in a winze. At the south end of the El Oro mine, I saw some Mexicans sinking a winze below the 286-foot level and they were down over 80 feet on a dip of 65°. All the rock they broke was being carried in sacks on their backs from the bottom of the winze to the level, and they were being paid 15 to 20 pesos per metre for a winze 3 feet wide by 6 feet long. In the Mexico mine, winzes 5 by 6 feet cost 25 to 30 pesos per metre. The shift-bosses in the Esperanza mine are mostly Italians (Piedmontese); they are among the best miners in the world and learn Spanish readily; in a month they acquire a working knowledge of the language and they seem to know how to manage the *peones*. Most of the Piedmontese in the Esperanza mine come from Bisbee, Arizona, simply because the foreman worked there at one time.

Boys are employed underground for minor tasks, such as doing errands, carrying water, and cleaning tracks. They are only 8 to 10 years of age. On the whole, the full-grown workmen are not well built, they have the physique of a big boy rather than that

of a mature man; their strength is all in the back, the muscles of which have been developed by generations of burden-carrying. They can transport enormous loads on their shoulders, but are incapable of carrying any weight in their hands.

At the Esperanza there are 3,952 men employed; scarcely three per cent are whites. For some tasks it is necessary to use four or five Mexicans to accomplish what one white man could do, but on other work the Mexican will do what the white man cannot do at all, especially as regards carrying loads. The Mexican will often serve where a mechanical device would cost more.

When working in the mines the natives are naked save for a loin cloth and sandals (*guaraches*), for the air underground is very warm. On the second level of the Mexico mine it was 85°; in the shaft (owing to steam-pipes) fully 100° F. In the cross-cut from the 286-foot level going west from the Somera shaft the temperature was 95°, and in the cross-cut at 1,086 feet, it was up to 105°, by reason of poor ventilation and escaping steam. The general temperature in the workings is 60° to 70°. The heat is due largely to the action of water on the lime in the shale—slaking it—and it may be due also to the crushing of the shale, which is often seen to press heavily on the timbers.

At Guanajuato, it is estimated that it takes 2 to 2½ Mexicans to do the work of one capable white miner, but the native is paid one-fifth the wages given

to the other. The men seen in the mines are undersized, they have the physical proportions of an American boy. In the mountainous regions, as in Durango, the miners are bigger and stronger, and on contract work they can earn twice as much as the Guanajuatenses. Owing to *fiestas*, it is found that in employing a gang of *peones* on such work as excavation, it is necessary to carry 100 men on the payroll in order to have 30 always available, that is, they work one-third time.

By a town ordinance the miners are compelled to put on trousers before appearing in the streets. In coming up or going down a shaft the *tanateros* sing *alabanzas* (or hymns) in rough time; it is a sort of chanty.

In drilling a 'down' hole, there is no difference worth mentioning between white and native labor; the Mexicans strike the drill 100 times per minute, and their short rapid blows will equal in final effectiveness the long body swing and harder blow, made one-half as fast, of the European or American. The Mexicans work in less space. I have seen 18 men working in a shaft 7 by 15 ft.; there were nine pairs, one man holding the drill and the other striking, the change of one to the task of the other being made with the celerity characterizing a drilling contest. They carry water for the hole in their mouths and squirt it out as it is required.

Like the Turk, the native Mexican is a great porter. In carrying weights, the load is hung by a

rope attached to a head-piece (*mecapal*), which is a nearly oval mat made of the *ixtle* fibre; it takes the shape of the forehead, and reaches down to the eyes, lying over the front hair and under the hat. The *tanateros*, or ore-bearers, can carry eight *arobas* or 200 pounds apiece; they will transport as much as that 100 feet up the stone stairways of the old mines. At the Prospero mine, each man carries four tons per shift a vertical height of 75 feet, and a length of 400 feet, at a cost of 50 centavos. At Guanajuato I saw some excavating for foundations done at 25 centavos per cubic metre, the rock being carried a distance of 200 feet across the gravel of a *barranca*.

They are good blacksmiths. At the Peregrina the native workmen took out the flues from a boiler that was in bad repair; they cut the tubes at both ends, and welded on an extra piece to make the original length. One smith and three helpers welded 24 tubes in 12 hours. The native blacksmiths are good drill-sharpeners, though better at shaping than at tempering.

Here is the place to tell the story of a strike that occurred near Guanajuato. Order is not difficult to maintain in a mining town like Guanajuato, because the people possess a lively respect for the representatives of the law. The strike at the Peregrina mine affords an example. In that episode there figured 500 *peones;* there came four undersized soldiers and a most unimpressive *jefe politico*. The *patio* was full of the striking miners, ready for a riot. The little *jefe*

told the manager to open the *patio;* the big doors swung aside; the four soldiers entered with their muskets clubbed and the *jefe* behind them with a drawn sword. The laborers scattered like rabbits, the four soldiers whacked all within their reach, the *peones* fled and fell over the dump; the strike was over!

The authorities keep a close grip on the native population. Strikes are rare. They occur occasionally in the cyanide plant, where the men who tram the sand are inclined to think that they do too much. El Oro has never had a big strike. Should there be any disorder or insubordination requiring serious action, the *jefe politico* (sheriff) is asked to call out his *rurales* (police) and these arrange affairs by capturing the ringleaders, after which the crowd scatters at once. The *peon* is an inveterate thief; the mill-hands steal ore and the precipitate in the zinc-room whenever possible. When caught in the act, the culprit is turned over to the *jefe politico* and in short order the latter sentences him to serve in the army. He is made a compulsory soldier and may be drafted to the hot country of the Yucatan peninsula, which is equivalent to exile. To put the *peon* in prison means nothing to him; he has a quiet time, his friends bring him food, he is required to clean the streets or do similar municipal work; it is no punishment to him; but to be placed in the army means wailing and the gnashing of teeth among his friends.

Chapter 16

PACHUCA — AN OLD MINING CENTRE — ANCIENT METHODS — THE DISCOVERY OF THE PATIO PROCESS — REVOLUTIONARY DAYS — THE INVASION OF THE MODERNS.

PACHUCA is approached from Mexico City over a railroad that traverses the wide volcanic plains covered with vast plantations of *maguey*, in serried lines stretching out like an army in skirmishing order. A journey of 62 miles brings the traveler to a white town at the foot of brown hills that rise to a range 1,500 feet above the valley, which is 8,200 feet above sea-level. The morning I saw them first, the mists still hid their summits and gave them the possibility of a greater height. Pachuca is like faraway Kalgoorlie in the matter of dust; it swirls round every street corner and smothers the picturesque in the dry folds of the commonplace. In the plaza, among the graceful pepper trees, there are two specimens of eucalyptus, fifteen to twenty years old, whose dark blue foliage and ragged columns told of a land unknown to the civilized world for 250 years after the Spaniard invaded Mexico. The antiseptic odor

of these gum trees recalled to me many a glorious day spent in the Australian Alps.[12]

The pepper trees that ornament Pachuca also came from a far country; they are called the Peruvian tree, having been introduced by one of the last of the Spanish viceroys, who brought them from Peru, where he had previously held office. The eucalyptus was introduced thirty years ago by the minister *de fomento*, but it has not done very well, the soil being too dry.

In every respect, save its dust, Pachuca differs from any modern mining town in English-speaking countries. The corrugated shanties and the white tents of ephemeral mining camps are here replaced by a solidity of construction that bespeaks a hereditary occupation. Massive stone buildings overlook the narrow cobble-paved streets and some of them have architectural pretensions, as for example the offices of the Real del Monte Mining Company, an enterprise of historic continuity and associated with names famous in mining, for John Taylor & Sons were engineers of the old company sixty years ago. Even to this day John Taylor's name is honored, and in the Santa Brigida mine there is a level that continues to be called the *cañon de Taylor*. Another reminder of the Cornish invasion is seen in the fine stone mansion, half smothered in beautiful bougainvillea, of

[12] For even in Australia there is mountaineering and snow. Go to Bright and Harrietville in Victoria during August and climb Feather Top or Mt. Bogong. *Experto credite.*

General View of Pachuca. Reduction Works in Foreground

THE PLAZA OF PACHUCA

Mr. Francis Rule, whom his countrymen called Capt. Frank Rule, and the Mexicans, Don Pancho, an honored and successful mining engineer.

Pachuca has a population of 40,000, and of this number 7,000 work underground. The district produces 6,000,000 ounces of silver per annum and 30,000 ounces of gold, representing 9,000,000 pesos or $4,500,000.

Most of the lodes that are productive today were discovered by the *conquistadores* and their immediate (Spanish) successors, aided, to some extent, by the natives (Aztecs). The Spanish pioneers sought for gold placers and extracted the metal—not much—that they found, by washing, supplemented sometimes by amalgamation. What silver ore they encountered, they smelted with carbonate of soda (the *tequesquite* of the Spaniard and the earlier *tequixquitl* of the Aztec), a supply of which came from the lagoons in the valley—for instance, in the lake of Tezcoco. Their fuel was charcoal made from fir and oak; possibly also they used some lead ore to collect the silver in their rudimentary smelting operation. When Bartholomé de Medina invented the Patio process at the Hacienda Purisima Grande he revolutionized the silver mining industry. This was in 1557; up to that time only the richest mineral could be smelted and there was no process for treating the low-grade ore. Medina was the first to apply amalgamation to silver, despite its much earlier application in gold mining. This was a basic improvement, but he

also elaborated the method for treating silver sulphides by chloridizing with salt in the presence of copper sulphate, using mules to mix the charge. This is the Patio process, so called because it takes place in an inner court or yard (the *patio*) and from Medina's day to this, for 350 years, it has been the characteristic feature of Mexican metallurgy.

In 1739 Pedro José Romero de Terreros, who had made money by mining in Queretaro, visited Pachuca and became impressed with the Real del Monte district. He spent his capital, said to have been $60,000, and borrowed more to carry out his explorations, but finally he struck a bonanza and won a big fortune. He gave the king of Spain a battleship and other large gifts; in consequence, he was ennobled. As Count of Regla he became the founder of a family of successful miners. They worked the mines until 1819, when the disorderly condition of the country, due to the revolution against the Spanish Government, caused operations to cease. A few years later the mines were sold to an English company, which took charge in 1824. The doings of that company are still mentioned in every Mexican guide-book, the writers of which dwell with gusto on their wild speculation in London and their reckless extravagance in Mexico. The £100 shares rose to £16,000 apiece, almost before a start had been made; enormous sums were spent at the mines, no less than 1,500 tons of machinery being hauled across the country from Vera Cruz. In 1848 the company went into liquidation, after extracting

$16,000,000 in silver and spending $20,000,000. In 1850 a Mexican company was organized, and it is this ownership that survives without important change to the present day.[18] The first manager of the Mexican company was the last manager of its English predecessor; that was John Buchan, obviously a Scotchman; and despite the change of ownership there was a continuity of management, the Spanish and the British members of the staff co-operating loyally. During the Maximilian days and the later successive fights for the presidency, the mines at Pachuca suffered from the depredations of the military, partly soldiers but mostly bandits. Stories are told of the miners having to live underground for days at a time and of the money that was buried in the levels when people at surface were being robbed without compunction. Up to 1890 it was necessary to carry a revolver in the streets of Pachuca, even in the daytime. The Real del Monte office, for example, is a massive stone structure which originally did duty as a fortress; the round towers, slotted for rifle-fire against attacking forces, still stand at each of the four corners of the building. Every mine even today is enclosed by massive walls, which at one time served as protection from assault, although nowadays they are retained for a different reason. They safeguard the dumps, which are recognized as having a possible

[18] Since this was written the Real del Monte mines have been sold to a Boston corporation. The Anglo-Celtic invasion has begun!

value in the future, for the *peones* are born thieves and their pilfering is a constant nuisance to the mining companies. For this reason also the reduction works, or *haciendas*, are enclosed within lofty walls, which are entered by arched doorways, guarded by a watchman. At noon the women crowd at these entrance gates with baskets containing the dinner of their men, who meet them there; they often squat down beside the wall to have a chat and share a smoke, until the lengthening shadow marks the time to resume labor.

All the *peon* employees of the mines and mills are rigorously searched by the *velador* as they pass out through the gate of the enclosure. The ordinary *peon* laborers are cheap enough, but it is what they steal that makes them costly. They are inveterate thieves. All sorts of precautions are taken. At the Hacienda Loreto, the manager proposes to make his men pass through a water-tank and compel them to shout "*Viva Mexico*" three times in order to detect any amalgam that they may have in their mouths. And they have other schemes for overcoming their excessive poverty otherwise than by earning scanty wages. For instance, there is a great deal of mutilated coinage and also of counterfeits. When pay-day arrives, the workman, in sweeping his silver across the office-counter, will try to palm off a spurious coin by claiming that the cashier gave it to him. The trick is detected by the warmth of the coin, which the man has held in his hand just before passing it in. Punishment for

this trick is severe, as it is an offence against the Federal Government; culprits are apt to get a sentence of several years in jail.

At Pachuca the application of mechanical invention to a basic industry is amusingly illustrated by the fact that even *tortillas*—the common pancake of the country—are made by machinery. The people of Pachuca patronize the establishment where this is done because the cost of the machine-made *tortilla* is one half that of the hand-made article and it is equally palatable. The excellence of the local *tortilla* may explain the vigor of the native miner; for the *barateros* of Pachuca are recognized to be the best miners in Mexico; they have learned from the Cornish, who settled in the district more than fifty years ago and intermarried with the natives. The Guanajuatenses, or men from Gunanajuato, have the reputation of being quarrelsome and less efficient as miners—which may be for lack of admixture with a strain of Cousin Jack, but we do not make the suggestion with any confidence.

The natives of this district, like most Mexicans, are wonderfully clever in estimating the silver content of an ore with which they are familiar; stolen ore is invariably bought by valuation at sight. Even the tributers (those that work on tribute or *partido*) sell the product of their work to the proprietary company on the basis of an estimate of its assay-value made at sight by an official termed the *rescatador*; if

the appraisal is not satisfactory, they can sell their ore elsewhere. Tributers get an eighth of the stuff they mine—that is, one sack in every eight—the remainder going to the company. This is the system at the Real del Monte mines; other companies work chiefly on contract.

Chapter 17

REAL DEL MONTE — OLD MACHINERY — THE VISCAIÑA LODE — ITS EARLY ROMANCE — LA DIFFICULTAD — AN ELECTRICAL PUMP — LODE STRUCTURE — LOCAL GEOLOGY — SCENERY.

WE, that is Robert M. Raymond of El Oro and the writer, made an interesting visit from Pachuca to the neighboring mining town of Real del Monte; this courtesy, and much information, we owed to Señor Don Carlos de Landero, the managing director and one of the most accomplished of Mexican mining engineers. In a large carriage drawn by four mules, with a driver and footman dressed in the picturesque uniform of the company, to the crackling of the whip and the heavy rumbling of the wagon over the cobblestones of Pachuca, we started on the morning of October 30, before the mists had uncovered the crests of the range where lies the treasure unexhausted despite the mining of three and a half centuries. Emerging from the narrow streets, the road cuts the edge of the valley and winds slowly among the brown hills, dotted with wild *maguey*. At the San Francisco shaft of the Santa Gertrudis company we saw a large pumping engine

of the Cornish type, built by Bickle & Co., of Plymouth, in 1898. The cylinder is upright and 90 inches in diameter; the stroke is 9 feet and the pump-column 18 inches. The capacity is 3½ cubic metres or 1,000 gallons per minute, from a depth of 400 metres. This pump was chosen by Capt. Frank Rule, under a former administration; it was obtained at an enormous cost, on account of the difficulties of transport and erection. Although made in 1898, it was not at work until 1902. But once erected, the pump has proved most efficient. The boilers are single-flue, with two fire-places and nine Galloway tubes, so as to be well adapted to the use of mine-water.

The distance from Pachuca to Real del Monte is six to eight miles, by the various roads. Haulage of ore costs three pesos per ton, the road crossing the summit of the range, 1,100 feet above Pachuca. Only one trip per day is made.

Nearing the divide, the road crosses the red outcrop of the Vizcaiña lode, famous in local mining annals as that which gave such wealth to the first Count of Regla. The story is worthy of repetition, although it has several versions, the most reasonable of which is here offered. In 1739, Pedro Terreros, who is said to have made $60,000 in the mines of Queretaro, happened to visit Pachuca. He was an experienced miner. Becoming interested, he abandoned the journey to Spain, and started mining at Real del Monte. Humboldt speaks of "the vein of la Biscaina or Real del Monte;" it is now spelt Viz-

San Francisco Shaft of the Progreso Co.

Sotol Shaft of the Maravillas Co.

THE MINES OF PACHUCA

Camelia El Carmen Paraiso

THE MINES OF PACHUCA

caiña (pronunciation remaining unaltered, but the Mexican orthography being substituted) and it is evident that the name was given after Terreros came there, for it refers to the country of his nativity, Biscay. Most sea-goers know the Bay of Biscay. Terreros was successful, but the increased flow of water compelled him to abandon the main Santa Brigida workings when they were 120 metres deep. In the early part of the eighteenth century the water in mines was hoisted by methods that still survive, namely, hide bags and a windlass. Even in Humboldt's day, sixty years later, much the same practice obtained. He says: "A bag full of water suspended to the drum of a *barritel* with eight horses (*malacate doble* or double horse-whims) weighs 1,250 pounds; it is made of two hides sewn together. The *malacate doble* has four arms, the extremity of each arm has a shaft (*timon*) to which two horses are yoked. The diameter of the circle traveled by the horses is seventeen *varas* and a half (that is, 47½ ft.); the diameter of the drum is twelve (32 ft.). The horses are changed every four hours."

However, the influx of water was finally overcome in miner-like fashion by driving a drainage adit (*socabon*) into the hillside. Humboldt says: "A very enterprising individual, Don Joseph Alexander Bustamente, was courageous enough to undertake a level near Moran; but he died before completing this great work, which is 2,352 metres in length from its mouth to the point where it crosses the Biscaina

vein. * * * The level was only finished in 1762 by Don Pedro Terreros, the partner of Bustamente. * * * The level of Moran traverses the Biscaina vein in the pit of San Ramon at a depth of 210 metres." But these worthy miners were plain 'José' and 'Pedro' until long afterward, when their wealth and public spirit led to their ennoblement. This adit of over a mile long was started in 1850 and was finished in twelve years; the smaller veins intersected during the progress of the work furnished funds for the continuation of the adit, but before it was completed the projectors of the enterprise were—as is usual in mining romance—down to their last penny. When the vein was cut below the Santa Brigida shaft, the adit was in bonanza. This was at 210 metres below surface. The orebody was worked for twelve years and the money secured by Terreros enabled him not only to equip the old mine but to buy large plantations in the vicinity. He became enormously wealthy; "this muleteer and illiterate shopkeeper," so says the chronicle, became Count of Regla. When his children were baptized the procession walked on bars of silver. Furthermore, he loaned money to his sovereign—this was one of the privileges of rich men in those days; nowadays they buy yachts and found trust companies. Humboldt says that Terreros "known by the title of Count of Regla, as one of the richest men of his age, had in 1774 already drawn a net profit of more than 25 millions of *livres turnois* ($5,208,750) from the Biscaina

mine. Besides the two ships of war that he presented to King Charles the Third, one of them of 120 guns, he lent five millions of francs ($1,041,750) to the court of Madrid, which has never yet been repaid him."

Near the summit of the ridge, at Hiloche, where the Pachuca road descends to Real del Monte, there is a fine grove of primeval oak, suggesting the forests that covered the plains and hills of Mexico before the Spanish conquest. A good purpose is shown in the young plantation of cedar and eucalyptus that has been started in this locality. Mexico has suffered enormously from de-forestation, and the laying out of trees ought to be one of the first duties of the Federal State authorities, as well as of public-spirited citizens. At Hiloche is the big pavilion built in 1901 for the entertainment of 600 people, constituting a party of the American Institute of Mining Engineers. That occasion is remembered by a great many who are now scattered over the mineral regions of North America. The pavilion has not been demolished; it is used for picnics.

Descending by a winding wagon-road we soon reached La Difficultad, at an altitude of 2,793.27 metres. This mine is one of the chief openings of the Real del Monte company. It affords, among other things, an interesting example of pumping practice. In the shaft-house there is an enormous engine of the marine type built by Richard Hartmann, of Chemnitz (Austria) in 1889. This operates

two stationary Rittinger pumps, with a discharge of 890 millimetres and a stroke of 2.5 metres; also a sinking pump of the same kind with 850-mm. discharge and 3-m. stroke. The capstan engine, for handling heavy pieces of pump and facilitating repairs, is from Tangye Bros., of Birmingham (England). These pumps have been replaced recently by a new Swiss pump, but they are kept ready in case of need. The Swiss pump comes from Sulzer Bros., at Winterthur; it has a capacity of 8,400 litres per minute to a height of 240 metres, delivering the water from the bottom, at 540 m., to a drainage level at 300 m. below surface. The pump was installed on July 23, 1905; it has four compartments, alongside, the water being forced from one into the next, each pump re-enforcing the other. It is operated by a 650-h.p. motor working with 380 h.p. and was taking about 4,000 litres at the time of our visit. The motor of this rotary pump was supplied by Brown Boveri & Co., of Baden, and is of the three-phase induction type. It is constructed to yield 650 h.p. at 60 cycles or 900 rev. per min., using 160 amperes at 1,100 volts. The pump-shaft is coupled direct to the motor-shaft. The motor was running at only two-thirds its normal speed, yet it was heating rather badly; this is characteristic of most Swiss motors. Although Swiss and German motors are cheaper, they have got no stamina and will not stand an overload like the American-made machines, some of which are actually guaranteed to carry an overload of 25 per cent for two

An Old Patio in Action

A CHILEAN MILL IN OPERATION
Note the Blindfolded Mules and the Men Bringing Ore in a Hand-Barrow

hours or even longer. No suction is used, the pump draws from a dam that affords a 50-ft. head. The pressure in the column is 25 kilograms per centimetre. The sump under the rotary pump is three metres deep, the water from it being raised to the dam by a Knowles pump geared to a motor, which gets its impulse from a Koerting elevator, operated by a stream of water descending from the 300-m. level. These Swiss centrifugal pumps are used in other mines at Pachuca and they are said to be highly satisfactory; they have a particular and effective arrangement of the runners; the makers of them are willing to guarantee a specific efficiency, which, as yet, American manufacturers will not do. Four of these Sulzer pumps (each of 1,500-gal. capacity) have been ordered for the El Oro mill, to raise the return water and solution from below the zinc-room. At the pump-station there was the usual shrine with lighted candle on each side, and ornamented with artificial white flowers. Here we had a timely luncheon and a pleasant talk with the engineers of the mine.

The first 50 ft. of the shaft is lined with masonry supported by arches sprung from the country-rock. The shaft is not continuous; from the 440-m. level there is a counter-shaft to the bottom. This is descended on a cage with steel-rope guides. At the 440-m. level there are some large underhand stopes; when the flat cable is worn out, its separate strands are used for hoisting ore underground, in hides that hold 25 kilograms apiece. These are not made in the

shape of buckets, but they are laid flat, the broken ore is put on them and then they are laced so as to make a parcel. The ore hoisted by windlass in this way is discharged into side-dumping cars, which are run on a wooden track lined with an iron band to the station at the shaft, where the ore is dumped onto a platform to be shoveled into a skip. Altogether, it affords a curious mixture of old and new methods; it is a hybrid practice. At the 463-m. station we changed from the counter-shaft to the main shaft, and while waiting for the cage we watched some men who were loading the accumulated waste into ox-hides; these held 300 kilograms, or the third of a ton, and after being laced they were hung by chain to the bottom of the cage, the material being used at the next level for filling. All the rock broken in shaft-sinking is raised in this way, and even water, just as they did in the days of Pedro Terreros. As the five men filled and then laced the rawhide, they put it aside for the next trip of the cage; when I first saw it, I thought it was the carcass of a dead mule, and it smelt like one.

In walking through the workings, one notices that the cross-cuts are walled up, the walls being often sealed with clay to divert the ventilation. There is a good deal of masonry in the mine, and different parts of it are shut off by iron gates, so as to prevent pilfering. There is no timbering worth mention. The ore is mainly quartz; it is often ribboned by the banding of rhodonite and sulphides (iron pyrite and argentite); in many respects it reminded me of the

veins in the Alice and Lexington mines, at Butte, Montana. The accompanying sketch (Fig. 17) of the Santa Inez vein is a fair example of the lodes in the Difficultad mine. Both walls are well defined; on the foot (*G*) there is a wet slip; *E* is a band of rhodonite; *D* is mainly amethystine quartz; *F* and *B B* are sulphide streaks; *A B* is massive poor quartz; *B* to *C* is mottled by brecciation; between *D* and *E* there are

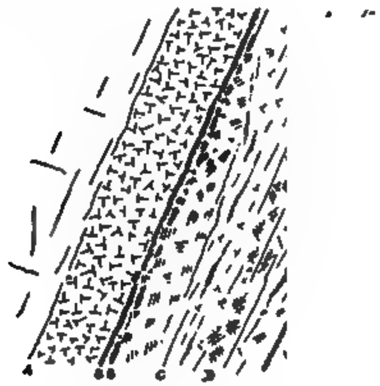

Fig. 17.

streaks and spots of sulphides, including argentite, a little galena, and occasional yellow zinc-blende; *E F* is brecciated andesite, now partially silicified; *F G* is crushed quartz. The whole width of lode is seven to eight feet. At the Difficultad mine, the low-grade ore left on the dump is said to contain 400 grams of silver and 2 grams of gold. This affords an idea of the cost of working. At the Barron mine, the ore

is said to average 800 gm. silver and 4 gm. gold, while in the Difficultad it is said to carry, for an average of eight metres, not less than 1 kilogram of silver and the usual proportion of gold.

It may be added that the prevailing formation about Pachuca is andesite; the veins are lines of fracture which have been healed by silicification. There exist in the district several islands or caps of basalt connected with vents and there are dikes of rhyolite accompanied by slight mineralization along their walls. For details of the geology, the reader is referred to a valuable paper by Señor Ezequiel Ordoñez.[14]

On leaving Real del Monte by the southern road a good view of the surrounding country is obtained by looking back. To the left is a rounded ridge clothed with groves of oak; to the right, a conical hill surmounted by a coppice of dark oak and cedars of Lebanon, and under their shade the white-walled English cemetery where many a Cornishman has gone underground for the last time. Between these flanking hillslopes, framing a picture, there are the white houses and red roofs of the town, surmounted by Moorish church-towers, among which, curiously out of place, is the Cornish engine-house with its lofty chimney rising above the castellated enclosure of the Difficultad mine. Behind the town are green hillsides, and further back, after the interval that marks

[14] 'The Mining District of Pachuca, Mexico,' *Transactions* American Institute of Mining Engineers, Vol. XXXII, pp. 224-241.

a deep *barranca* or gorge, there stands, outlined against the blue sky, the mountain crowned by the battlemented rocks of Zumate.

After crossing the summit and beginning the long descent to Pachuca, there is much to be seen that typifies the Mexico of today. The broad and winding road cuts through gray-purple andesite; it is lined with massive stone culverts and does credit to the engineers responsible for the construction. It skirts brown hillsides, darkened in spots by the wild *maguey*, with the tall central stem that is the sign of an uncultivated condition; there is an occasional cactus and a few palms, mainly the *izote* from the fibre of which are made the straw hats of the *peones*. Whitewashed monuments dot the surface and, in their occasional sequence of direction, mark the boundaries of mining property. Yellow scrub fringes the road and enhances the value of the purple in the distance. A flock of sheep, a string of patient donkeys laden with charcoal from the forests, other *burros* coming from the valley and laden with pigskin bags inflated with their burden of *pulque*; some sad-faced Indian women trudging up hill, one of them with a baby slung in her *reboso*, another walking patiently while her man rides alongside on his mule; then a cavalier with wide *sombrero* and gaily caparisoned saddle, a *serape* thrown over the silver-mounted pummel and riding his horse superbly; a wagon heavily laden with sacks of ore, its brakes crunching noisily, drawn by ten mules, with silver bells, and driven by a brigand-like muleteer; all

these are part of the stream of life that we pass or meet on this road. But the foreground is not all the picture; at our feet, to the south and west, lies outspread the vast plain known as the valley of Mexico, crossed by white streaks of dusty road, checkered by squares of cultivation, the yellow patches of maize, the green of barley, and the occasional darker shade of alfalfa, with other rectangular lines that mark the serried rows of *maguey*.[15] Sunlight and shadow shift over the vast expanse; in the distance, more than 16,000 feet high, rises the snowy crest of Ixtaccihuatl —'the white woman'—partially veiled in a cloud, and by the Aztec name recalling the pathetic fate of an ancient race. In middle distance there is a blue ridge behind which is Mexico City, and to the right, under the mountain of San Cristobal, hides the dusty town of Pachuca; in front are several famous mines—Corteza, El Lobo, Santa Gertrudis, Barron, and La Blanca—each in its walled enclosure and dominated by a towering shaft-house of stone. And then, before we realize it, we are awakening the echoes of the narrow streets of Pachuca, and amid the cracking of our *cochero's* whip and the warning shouts of those that clear the way, we pull up at the railway station, just in time to catch the train.

[15] There is no *maguey* on the west coast of Mexico; only one-tenth of the population of the entire country drinks *pulque*, chiefly in Mexico City and its vicinity, including such mining towns as Pachuca and El Oro. It is unwholesome because it is drunk when still in process of fermentation; if the people did not take this stimulant they would take some other.

Chapter 18

THE REDUCTION WORKS OF PACHUCA — THE HACIENDA DE GUADALUPE — TREATMENT ON THE PATIO — A METALLURGICAL SURVIVAL — SOME CRITICISMS.

PACHUCA is proud of its *haciendas de beneficio* or reduction works, of which there are seven large ones. Six of these are in operation and they treat 5,000 tons per week. Three of them are custom works; those of Guadalupe, La Luz, and Loreto are not. At the entrance of the *haciendas*, and even of private residences, one sees the big iron hoods of the mercury retorts. They are buried in the ground, one on each side of the gateway and, being 5 to 5½ feet long, they have the appearance of spiked guns.

The Hacienda de Guadalupe treats 900 tons per week, this being the output of the Santa Gertrudis and Guadalupe mines. At the mine the ore is broken by hand, and picked over; the 'best selected' assays over 10 kilograms of silver per metric ton and is sent to Europe, the second class, carrying less than 10 kilograms, but over 2 kg. per ton, is shipped to the smelter at Monterrey, while the mine-run, containing less than 2 kg., comes to the *hacienda*. Here it is screened to ¾

inch, the oversize passing through Cornish rolls, while the undersize is shoveled into bins. These are built of stone; they are brick-lined at the opening, whence the ore falls into cars that take it to Chilean mills. The oversize, after passing through the rolls, goes through a trommel (2 ft. diam. and 3 ft. long) with half-inch openings, the oversize going back to the rolls while the undersize falls to the ground, to be shoveled into cars, in which it is taken to bins above the Chilean mills and subsequently fed into them by shovel. There are 14 Chilean mills; the die-rings (5 ft. inner diam., 6 ft. outer) and shells are composed of Siemens & Martin steel, made in Germany. The die lasts one year, the shells twice as long. There is an iron ring inside the steel shell. Each mill (inside diam. 1.85 m.) has six openings, guarded by a 60-mesh screen, all on one side. The discharge passes into a vat, whence it is raised by a centrifugal pump to distributors above the 14 concentrators. These are vanners—with belt 1.8 metres wide—known as the Johnston table and manufactured by the Risdon Iron Works, San Francisco. It does good work, the belt being heavy, so as to give it the motion of a *batea* instead of being simply supported on a frame. The concentrate is shipped to Europe; it contains 14 to 15 kg. silver and 100 gm. gold per ton. The yield (from 900 tons of crude ore) is 21 tons per week, of which 13½ tons come from the vanners and 7½ tons from canvas tables that receive the tailing from the vanners.

The tailing that results from this concentration process goes to vats or bins; these are structures built of masonry, 4 to 5½ metres deep. Here the pulp settles and the water is drawn off to a well, from which it is pumped for use in the mill. Stated briefly, the process of ore reduction consists in grinding fine with Chilean mills, extracting the heavy sulphides (with their associated gold) on concentrators, and then treating the tailing (containing the bulk of the silver) by amalgamation on the *patio*.

On the flat ground below the terraced slope forming the site of the mill just described, there stretches the broad expanse of the *patio*, where the process of that name is carried out. *Patio* means a yard or enclosure, and the process derives its name therefrom. The *patio* of the Hacienda de Guadalupe is the size of a city square, it is paved with stone and divided into rectangular spaces, 30 by 25 metres, in which twenty separate charges or *tortas*, each weighing 300 tons, are undergoing various stages of treatment. Each bin or vat that holds the pulp or tailing from the concentrators, has a vertical opening 5½ feet wide which is kept closed by a series of boards (6 to 9 in.). These are removed one by one so as to allow the sludge to flow along the canals—3 ft. high, 6 ft. wide and built of stone—that lead into the *patio* itself. The flow of the sludge is assisted by a scraper (*camon*) pulled by a horse. This scraper is a plain plank, two inches thick, to which chains, connecting with the traces, are attached, as shown in the photograph facing page 134.

El camonero, the horse that does this duty, must be strong, for the work is hard; he scoops the slime along, to the accompaniment of much splashing and the encouraging shouts of the driver who controls the operation. Openings, at various points along the canal, serve to distribute the slime to separate rectangular stone-paved spaces, where the chemical work is done. Each rectangle, 25 by 30 metres, is delimited by two timbers (4½ by 8 in.) placed one over the other so as to make a partition 16 inches high. The *torta* that they enclose is 30 centimetres thick.

The slime or *tama* is allowed to thicken, by loss of moisture through evaporation. Then comes the addition of the first chemical, common salt, which is thrown over the charge like a shower of hail. The salt is obtained from the lagoons near Zacatecas and is added in the proportion of 6 to 7 per cent of the weight of the ore. This is an excess, but it is found to accelerate action and to diminish the consumption of mercury. After this part of the process (called *ensalmorar*) is finished, the mixing or *repaso* begins. This is done by the trampling of horses or mules. One man, himself on horseback, drives 12 animals, four in a row, tied by the neck to each other. The cracking of the whip, the slushy tramp of the horses, and the shouts of the driver give animation to the scene. This goes on by day only, from 7 in the morning until 2 o'clock in the afternoon. When the day's labor is ended, the horses are driven through a big tank to be cleansed, when more shouting and splashing enlivens

the *hacienda*. This mixing continues for 24 to 30 days. Each afternoon every portion of the *torta* is turned over with shovels in the hands of 12 to 15 men. After the first three days comes the addition of copper sulphate (bluestone) followed by further mixing, and then the mercury is introduced. The 'bluestone' comes from the United States; it is added to the *torta* in the proportion of 0.4 to 0.6 per cent of the weight of the ore. In looking over a *patio* in which the charges are in various stages of treatment, some just salted, others just showered with copper sulphate, the contrast between the rectangular patches of white and blue leaves a vivid impression. The mercury is added in the ratio of fully eight times the amount of silver estimated to be in the charge undergoing treatment. It is carried in a cloth, folded like a bag, and swung freely, so that the mercury squeezes through in the form of small globules. This is done to ensure thorough assimilation; the operation being appropriately termed *incorporación*. Five or six men perform this work, on the fourth day. At the end of the process (after 24 to 30 days, as determined by test) more mercury is added, in the proportion of 5 kilograms of mercury for each kilogram of silver present in the charge, making about 2,500 kg. to each *torta*, this being introduced for the purpose of collecting the amalgam already formed. This operation is termed the *baño*. During the continuance of the treatment the *torta* is tested by panning

samples in clay saucers (6 in. diam.) called *jarros*. The operator pans the stuff down to a button of mercury and squeezes it between the thumb and index finger, to test its consistence, a flat bit of amalgam remaining, of a size indicating the extent to which amalgamation has proceeded. The rejected sand from this panning undergoes the ordinary fire-assay; when there is no further decrease in the content of the tailing, complete extraction is indicated and mixing on the *patio* ceases.

Then the horse with the scraper (*camon*) is employed to move the charge forward to a sump or *lavadero*, the *patio* being finally swept clean by 12 to 16 *peones* with brooms; the mercury can be seen in small pools and is splashed about during the manipulation required for this clean-up. The charge is moved to a basin (*cajon*), 8 by 10 ft., where seven men, standing in water just over their knees, stamp around, and stir the stuff, while clean water is being added and fresh material is being fed into the *cajon*. The top of this basin is level with the floor of the *patio*; the bottom of it is six feet below the pavement and is enclosed in masonry, except on the lower or outlet side, where there is a barrier made of two boards, which are perforated with 3-inch holes, twelve of them, in clusters of six each. The amalgam and mercury collect at the bottom, while the overflow drops into large cast-iron hemispherical basins (*apuros*), of 2½ ft. diam., which serve as traps. There are five of these,

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G. Mechanical Plough. H. Horses Mixing. K. Men Shoveling

Two Views of the Patio Process

distributed along the exit-sluice below the sump. From the last *apuro*, the pulp flows over two parallel sluices with riffles, and in this a dozen or more boys, 8 to 9 years old, stamp around, in order to aid the separation and arrest of any escaping amalgam. These little fellows, chocolate colored, with big straw hats and thin bare legs, are kept on the move, so as to stir the slime; they wade around at the bottom of a canal 10 to 12 feet below the level of the *patio*. They receive 37 centavos, or about 20 cents, per day. Most of the amalgam is caught in the sump and in the first two *apuros* at the head of the sluices. This clean-up occupies 16 to 17 hours. Finally, the rich deposit at the bottom of the basin is washed, one of the boards of the lower barrier being removed, while fresh water is turned in. What amalgam gets out of the *cajon*, lodges in the first (and biggest) *apuro*. At the very end of the operation more water is added; the *peones* use scrub-brooms and sweep the bottom clean. The amalgam and mercury make a big showing; they are lifted in iron ladles; these are made from the flasks in which the quicksilver is bought, their tops being cut off, and an iron handle inserted. From 1,500 to 2,000 kilograms of amalgam are obtained from the clean-up of a single *torta*.

Six hundred horses are used on the *patio*; they last four or five years, if young; the older ones last only six months. They become poisoned by the copper sulphate; hence the washing each day. Some

of the horses are found to gather a lump of amalgam in their stomachs, as much as half a kilogram, say, one pound. This used to be removed when the horse died, but now the Government claims the deceased animal, without permitting dissection, and it goes to the crematory. What happens to the silver amalgam is not stated.

The extraction is 80 to 85%, the tailing (*jales*) containing 100 to 150 gm. silver, say, 3 to 5 oz. per ton. The gold is caught in the concentrate on the vanners; practically none of it is saved on the *patio*. Nevertheless, down the creek there are two plants that re-work the tailing from the *hacienda*. To anyone accustomed to stamp-milling, it is surprising how the mercury is splashed about. The pavement of the *patio* itself must absorb some of it, for this pavement is made of slabs, which are irregular in size, but usually 1 by 1½ feet, of volcanic stone, a basalt called *recinto*.

In another part of the *hacienda* one can observe the working of a mechanical mixing machine, designed to be a labor-saving modification of the Patio process itself. In a rectangle, 20 metres wide and 75 metres long, a plough, with eight blades, moving sideways, travels up and down. It is operated through a ratchet gear by a man who sits on the machine, as it is pulled by an endless cable of one-half inch diameter. This treatment requires 45 days and gives the same extraction as the ordinary Patio

process. The superintendent prefers the old-fashioned horse method because it requires less time. It can be said truly that the trampling of the animals affords a better aeration of the charge than the mechanical plough, which appears to go through the sludge rather than turn it over. There should be more turning of the furrow.

Mechanical devices in place of animals were tried long ago and they have been used in different parts of Mexico, especially Sonora. In M. C. Roswag's 'Metallurgie de l'Argent,' there are descriptions of such substitutes, which in English are called 'kneading' machines and in Spanish *repasadoras*.

Other observations are permissible. The small boys that tramp about in the tail-sluice give their toes as riffles to assist the settling of escaping particles of amalgam. The stirring in the clean-up basin, as done by seven grown men, has its humorous feature, but it is effective. The method of moving slime onto the *patio* by the *camonero* is an absurdity at first sight, but it obviates a costly conveyor, and both horses and men are cheap at Pachuca. The Chilean mill affords better grinding than the pounding action of the stamp, although it seems strange to see the *peones* shoveling into the mills and then taking a rest, when a mechanical feeder would do it so nicely. The temporary canals made between the *torta* and the *cajon*, to confine the passage of the pulp, are kept tight with manure, the droppings of the animals on the *patio*,

thus contributing smells to the sights, a combination not uncommon in Mexico. There is a striking contrast between the modern vanning tables and the *patio* itself, the whole picture exhibiting a sublime disregard of all modern mechanical ingenuity as applied to the handling of material.

The accompanying photographs will aid the foregoing description. *A A* indicate the position of the Johnston vanners; *B B* are the sludge vats, with their outlet at *C C*. *D* is the *camon* or scraper. *E* is a canal or conduit for the slimed ore. In the three photographs given on the page opposite, the first shows the workmen mixing the charge, with the horses at work behind them. In the second, the men are mopping the floor of the *patio* and sweeping the amalgam into the basin or *cajon*, shown in the bottom illustration; here the work of separating the amalgam is finished and the men are cleaning up.

Three Stages in the Patio Process

Horses Treading the Charge

El Camonero
At the Hacienda de Guadalupe, Pachuca

Chapter 19

THE CHEMISTRY OF THE PATIO PROCESS—CHEMICAL EQUATIONS—OBSERVATIONS OF HUMBOLDT—LOSS OF MERCURY—CONTRAST OF POLICY.

THE Patio process has been used on a large scale and continuously since 1557, therefore it is probable that a great many have attempted, at various times, to investigate the theory of it; nevertheless, few have been bold enough to publish the results of their investigations. In offering a few notes, it is with the hope, mainly, of helping the younger students in our profession.

The right amount of bluestone[16] is important, for if it be insufficient, the copper sulphate is converted into the sub-oxide, which reacts on the mercury so as to sicken it, covering it with a film. The bluestone consists of the sulphate of iron as well as of copper, for it is formed by the roasting of chalcopyrite; these sulphates react on the sodium chloride so as to liberate hydrochloric acid, which, according to Ortega,[17] first forms cupric chloride and then, in the presence

[16] *Magistral,* an impure mixture of copper and iron sulphate, was formerly employed. Bluestone, commercial copper sulphate, has replaced it in practice.

[17] 'The Patio Process for Amalgamation of Silver Ores,' by Manuel Valerio Ortega. *Transactions* American Institute of Mining Engineers, Vol. XXXII, pp. 279-282.

of mercury, cuprous chloride and mercurous chloride. The cuprous chloride absorbs oxygen and then reduces the silver sulphide in the ore, with the formation of mercuric sulphate and the liberation of the silver. Thus:

$$2NaCl + CuSO_4 = Na_2SO_4 + CuCl_2$$

$$CuCl_2 + Hg = CuCl + HgCl$$

$$CuCl + 4O + Hg + Ag_2S = CuCl + HgSO_4 + 2Ag.$$

On being liberated, the silver immediately forms an amalgam with the excess of mercury.

On the other hand Bustamente[18] claims that the iron sulphate in the *magistral* is essential, the rôle of the copper being, in many respects, subordinate, although necessary, to the iron. According to his explanation, ferric chloride is formed; this, on being reduced to a lower chloride, releases chlorine, which, while nascent, acts upon the silver mineral, transforming it to a chloride. A subsequent reaction with the hydrated oxides liberates the silver and hands it over to the mercury, for amalgamation. The copper sulphate acts as a carrier of oxygen and the presence of it is required to preserve the mercury in a metallic state.

The old theory, to be found in most text-books, was that after the cupric chloride was formed, a reaction with the silver sulphide mineral, in the presence of air, yielded cuprous chloride and argentic

[18] 'A Study of Amalgamation Methods, etc.,' by Miguel Bustamente, in *Transactions* American Institute of Mining Engineers, Vol. XXXII, p. 489.

chloride, the argentic chloride coming in contact with the mercury, so as to form an amalgam, together with mercurous chloride, thus:

(1) $CuSO_4+2NaCl=CuCl_2+Na_2SO_4$

(2) $2CuCl_2+Ag_2S=2AgCl+Cu_2Cl_2+S$

(3) $2Ag_2S+4Cu_2Cl_2+6O=4AgCl+2(CuCl_2+3CuO)+2S$

(4) $2AgCl+3Hg=Hg_2Cl_2+Ag_2Hg$.

It is a complex bit of chemistry, rendered obscure by the lack of accurate data. The Patio process is rarely checked by systematic analyses and assays, so that, despite the three centuries and a half during which it has been used in Mexico, there is but little evidence available. One or two points stand out clearly. If silver chloride be formed directly from the action of the chlorine liberated from the salt, and if this be a necessary chemical stage, why is it that ore containing hornsilver or natural silver chloride cannot be treated successfully by this method? If copper sulphate be the sole active agent in the *magistral*, why is it that the pure copper sulphate gives such poor results? If there is no direct chlorination of the silver, why is so much salt required? The first two queries have been answered; the last can be explained on the ground that the brine serves as a solvent for the cuprous chloride, rendering it more active as a carrier of oxygen.

Humboldt makes several interesting remarks[19] concerning the process of amalgamation on the *patio*,

[19] 'Political Essay on the Kingdom of New Spain.' Black's translation. Vol. III, Book IV, p. 268.

as carried out during his visit to Mexico, a hundred years ago:

"The process invented by the miner of Pachuca is one of those chemical operations, which for centuries have been practised with a certain degree of success, notwithstanding the persons who extract silver from minerals by means of mercury, have not the smallest acquaintance either of the nature of the substances employed, or the particular mode of their action. The *azogueros* (or amalgamators) speak of a mass of minerals as of an organized body, of which they augment or diminish the natural heat. Like physicians, who, in ages of barbarism, divided all ailments and all remedies into two classes, hot and cold, the *azogueros* see nothing in minerals but substances which must be heated by sulphates if they are too cold, or cooled by alkalies if too warm. The custom which was already introduced in the time of Pliny, of rubbing metals with salt, before applying the amalgam of gold, has undoubtedly given rise to the use of muriate of soda in the process of Mexican amalgamation. This salt, according to the accounts of the *azogueros*, serves to clean and to unskin the silver, which is enveloped with sulphur, arsenic, and antimony, as with a skin (*tililla* or *capuz*), whose presence prevents the immediate contact of the silver with the mercury. The action of this last metal is rendered more energetic by the sulphates with which the mass is heated; and it is even probable that Medina only employed simultaneously the sulphate of iron and

copper and the muriate of soda, because he discovered in these first attempts, that salt was only favorable to the process in the minerals which contained decomposed pyrites. Without having any clear idea of the action of the sulphates on the muriate of soda, he endeavored to recompense (*refaire*) the minerals, that is, to add *magistral*, to those which the miner considers as not vitriolic."

The 'hot' and 'cold' condition—called *calentura*, or fever, and *frio*, or chill—are untechnical references to oxidation and reduction, the sulphates contributing oxygen as fuel to the chemical reactions, while the alkali of the lime, ashes, or cement copper employed to doctor a 'hot' *torta*, neutralizes any excess of acid sulphate. The idea that the silver of the argentite was coated with sulphur, which had to be removed to permit of contact with mercury, illustrates the ignorance of what constitutes a chemical compound. The sodium sulphate is formed by the reaction between the "muriate of soda" or common salt and the copper sulphate, so that the addition of it simply anticipated a reaction consequent upon the use of *magistral*. The mention of "decomposed pyrites" suggests the agency of iron sulphate in the Patio process, an agency the exact working of which is yet a subject for debate among metallurgists.

Further on, he explains how, by the leaden look of the mercury, they inferred the commencement of chemical action; when a fine gray powder was sep-

arated from it so as to stick to the fingers, they said the paste was too 'hot' and they 'cooled' it by adding lime. If it preserved its metallic lustre, or was covered with a reddish pellicle or film, if it did not appear to act upon the mass, the amalgamation was considered too 'cold' and they endeavored to 'heat' it (*calentar*) by mixing *magistral*.

The "leaden look of mercury" is due to excess of copper sulphate, with formation of flouring mercuric chloride, which, in the presence of sunlight and organic matter (such as the droppings of the horses or mules that trample the *torta*) is converted into oxide; this is almost insoluble in the brine, formed by the excess of salt, and in consequence it is apt to be lost in the *torta* when it is finally discharged after treatment. When the *torta* is cold, the mercury is apt to show 'flouring'; it is in minute globules that do not coalesce, being coated with a reddish film of copper sub-oxide, because there is not enough of the copper sulphate present to generate chlorine from the salt, so as to form cuprous chloride.

At first the charge was mixed by the treading of a number of bare-footed workmen, but in 1783 Juan Comejo brought, from Peru, the idea of using mules. The Government granted him a privilege for it. This decreased the expenses of the process by one-quarter.

Then Humboldt continues: "It has been long proposed to cover the surface on which the pastes

repose with plates of iron and copper instead of flags; and it has been endeavored to stir the mass by working it with ploughs of which the share and coulter should be made of the metals mentioned, but the mules suffered too much from this work, the *schlich* (slime) forming a thick and by no means ductile paste." Finally, he concludes: "The process invented by Medina possesses the great advantage of simplicity; it requires no construction of edifices, no combustibles, no machines, and almost no impelling force. With mercury and a few mules to move the *arrastres*, we may, by means of amalgamation *por patio*, extract the silver from all the meagre minerals near the pit from which they are taken in the midst of a desert, provided the surface be sufficiently smooth to admit of the establishment of the *tortas;* but this process has also the great disadvantage of being slow and causing an enormous waste of mercury."

How great this waste of mercury was, it is difficult to realize today when the old tailing has been washed by several generations of patient *peones*, or else scattered abroad by the torrential rains of the tropics and the dry wind of the high plateau. They used eight parts of mercury to one of silver. At El Oro the mill of 100 stamps was run for six years without the purchase of a single flask of quicksilver. The tailing heap of the old *hacienda*—built 30 years ago—gave all the mercury wanted. In cyaniding the tailing, the mercury was dissolved, to be precipitated in

the zinc-boxes with the gold. The precipitate was retorted in order to drive off the water and the quicksilver. Out of a retort of 1,000 pounds there would be obtained 150 pounds, or two flasks, of quicksilver. Another suggestive incident may be mentioned. Nearly two years ago, when the mechanical ploughs (*repasadoras*) were installed at the Loreto mill, a cement floor was laid down, and in excavating for this purpose a big find of quicksilver was made, the earth being saturated with it. It is said that mercury worth more than 30,000 pesos was obtained.

As Humboldt said, the Patio was successful despite the ignorance of any chemical reactions involved. It is only recently, when the process is being discarded for more effective methods, that the chemistry of it has been investigated intelligently. As used for 350 years it was an empirical process, regulated by the experience obtained with the particular ore of each district.

The Patio process was invented when men, horses, and time were cheap, when there was no haste to realize on the ore in the mine. And this spirit survives; when I asked one of the Mexican engineers why they did not exploit a certain rich mine on a larger scale, he said that the shareholders did not care to rush the production because they feared the mine might be worked out too soon. This is the European idea of fifty years ago; the opposite of it is the American notion that it is best to gut a mine

A Typical Patio

MIXING THE CHARGE ON THE PATIO

expeditiously and make the maximum money in the minimum time. Both extremes are extravagant.

Pachuca affords examples of other methods besides the ancient Patio process. Some of these I shall describe in the next chapter.

Chapter 20

OTHER METALLURGICAL PROCESSES — THE HACIENDA LA UNION — KROENCKE'S METHOD — TUBE-MILLS—THE BARREL PROCESS—FRANCKE'S PROCESS — CHILEAN MILLS — RETORTING THE AMALGAM — THE PLANILLA.

T the Hacienda La Union there is much that is interesting to the metallurgist. The process is that of Kroencke, used in Chile, but modified by the manager, Francisco Narváez, formerly a captain of artillery and graduate of the military engineering school of Chapultepec. As a military officer he visited the United States three years ago, and, becoming much interested in metallurgical practice, he resigned from the service to undertake the work for which he has since shown so much aptitude.

The scheme of milling involves first a Sturtevant roll-crusher, which reduces the ore from 3 or 4 inches to 3/8-inch diameter. An Imperial shaking-screen sizes the material to 16 mesh; the undersize is fed into an Abbé tube-mill of 5-foot diameter and 22 feet long, while the oversize passes through rolls without springs, with 14 by 27 inch faces (made by the Denver Engineering Works). The amount of iron that gets

into the pulp is only 2 per cent; this fact is important in view of the chemical treatment that follows. Capt. Narváez was led to adopt this method by reading the book on 'Ore Dressing,' by Robert H. Richards.

Later on, without stopping the regular operation of the mill, he intends to replace the barrel-amalgamation process by cyanidation; as far as grinding is concerned, his results indicate that Chilean mills will more than hold their own against the competition of newer devices for pulverization. They permit of a very fine grinding at a low cost per ton. From an average of thirty sizing tests, made on the product of the Chilean mill at this *hacienda*, Capt. Narváez obtained the following results:

	Percentage.	Assay in silver. Grams.	Percentage of assay-value retained.
Finer than 200 mesh	80.00	1,290	93.65
Between 200 and 150 mesh	4.75	626	2.69
" 150 " 100 "	13.45	385	0.47
" 100 " 80 "	1.50	355	0.48
" 80 " 60 "	0.41	346	0.01

The original assay of the ore gave 1,102 grams per metric ton. One of these mills, for example, worked from February to June without stopping once for repairs; and with the ordinary unskilled labor, it ground 15 to 18 tons per 24 hours from 1½-inch size to the fineness recorded in the tests just quoted. The cost per ton did not exceed one peso, or less than 50 cents per ton.

At the time of my visit there was one Krupp tube-mill, with other foundations ready for the Abbé

tube. The Krupp tube crushed 50 tons to 100 mesh in 24 hours. It was preceded by a Krupp ball-mill, which reduced the ore from 1½-inch size to 24 mesh. It is necessary to grind dry, on account of the barrel process, which constitutes the main feature of the treatment. With the use of Chilean mills, as at the time of my visit, it was necessary to dry the product. Both ball-mill and tube work dry. Silex linings in the tube last three years. The use of the Chilean mills yields iron that becomes oxidized by the water, while the iron worn away from the balls in dry crushing through the Krupp mill, is in a metallic condition and in an amount suited to the later chemical reactions in the barrel. The ball-mill is charged with four balls of eight kilograms each per day, this representing the iron abraded from the balls themselves and the lining also. For setting the silex lining in the tube, a common cement with two parts of sand is used; it sets in three days. Trouble has been made by the fact that some of the sectional pieces of lining are not cut to the right curve; however, only three dropped out after being in use for a month. The flint pebbles are bought from Indians, who will not divulge the locality where they find them. They are paid 35 pesos per ton, while the imported pebbles cost 75 to 90 pesos per ton. The tube has no screen, the material passes through the length of it and is then discharged.

In the new plant as it will be re-arranged, the Krupp ball-mill will deliver its product to the Abbé tube, for re-grinding, and both will work wet, instead

of dry. The ore that goes to the Chilean mills will be crushed to 1½-inch size in a breaker and from the Chilean machines the pulp will be pumped direct to the vats and cyanided. From the day (in January, 1906) that E. M. Hamilton, associated with Charles Butters, made a cyanide test on the ore at this *hacienda*, Capt. Narváez has made more than 200 tests, obtaining an extraction of 98.12% on the silver and 88.4% on the gold. He believes that extraction of the gold is less than that of the silver because the gold is encased in the pyrite and, to liberate it, re-grinding is imperative. But the ore contains only 5 grams of gold per ton, therefore it remains yet to be proved, by further experiment, whether it will be necessary to re-grind more than 20% of the ore.

It was the custom formerly to use the *camonero* to move the product of the Chilean mills onto the *patio*, where it was allowed to dry in the sun, but the change to dry crushing will obviate the necessity for this practice. At the time of my visit, the Chilean mills were being operated without screens, the discharge being by overflow, thus saving labor while using a great deal of water, of which there was plenty. The tires on the Chilean mills are changed so as to equalize the wear; they last two years; the dies last only about eighteen months. Each mill requires 10 h.p. The Fraser & Chalmers, or Union, type of Chilean mill, modeled after Walker's patent, gives good service, grinding 15 tons per day; those of other makers treat only 8 or 9 tons, because the runners do not maintain

a vertical attitude. Seven Chilean mills ground 60 to 70 tons per day, while the Krupp ball-mill crushed 50 tons per day of 24 hours.

The product from the grinding machinery goes to the barrel-room. There are 13 barrels, originally made by Allis-Chalmers and since modified on the spot. Each barrel is beneath a hopper that holds a charge of 4.7 tons. As this is filled by the cars (each carrying half a ton) a grab sample is taken to determine the percentage of moisture and the richness in silver; from the aggregate of all these samples a mean of the iron assay is obtained for the week, so as to indicate if the amount be sufficient to effect precipitation; if not, zinc is added in order to help precipitation and also because it has been observed that the gold recovery is better when zinc is employed in addition to the iron. The cuprous chloride is proportioned to the amount of silver amalgam in the barrel, decreasing from, say, 60% Cu_2Cl_2 at the beginning of the month to 22 or 24% at the end. The silver in the charge is precipitated on iron. The barrel treatment consumes eight hours; it requires four hours to charge and discharge. Mercury is added half an hour after the treatment has begun. Salt is added in the ratio of 27 kilograms per ton of ore; no more copper sulphate is added than that required when making the copper chloride solution. The loss of mercury per month is 800 grams per kilogram of silver; the loss of silver is 6.88 to 9% when treating three charges per day.

The barrels are washed out once per month, during the remainder of the time the silver amalgam accumulates inside of them; it is taken out every other day, in such an amount as to yield 250 to 300 kilograms of silver bars.

From the barrels the pulp goes to six washers or agitators, and from them to *apuros* (or wells) underneath, where the silver amalgam is collected. Thence the tailing passes outdoors to a crude form of conical buddle. The 2,300 to 2,500 tons of tailing treated each month contain 110 to 120 gm. silver per ton and yield 25 to 30 tons of concentrate assaying 2 to 3 kg. silver and 30 to 40 gm. gold per ton.

When Cu_2Cl_2 is added, there is a formation of AgCl and sometimes of HgCl; then if zinc (in the form of strips of metal, not shaving) is added, the metallic silver is precipitated and also the mercury. Sodium hyposulphite was tried, but, although useful, it was not found necessary. The purpose of it was to regenerate the Hg from the HgCl formed, and the same end could be gained by the motion of the pulp in the barrel. If there is enough iron in the pulp, it will precipitate the silver, but the amount of iron is not under control, hence the addition of zinc if the iron be inadequate. From the wear of the lining and of the balls in the Krupp mill, Capt. Narváez was getting 600 gm. iron per ton of ore, this being the amount which practice has demonstrated to be necessary. Whenever, for any reason, the amount is less than as specified, zinc is added. Experience has proved

that, although 1,200 gm. iron is adequate to precipitate the silver in a charge of two tons of ore and give bullion 999 fine, yet zinc is always needed in order to increase the gold recovery. If this be done, the bullion will assay 960 gm. silver and 2.8 gm. gold per kilogram, while, if the zinc be omitted, the gold will not exceed one gram per kilogram.

The total extraction of silver by this barrel process is 95%; that of the gold is from 35 to 75%. In the concentrate, 5% more of the gold is saved. The gold is to the silver in the ore in the ratio of 5 to 1,000. The ore treated at the mill is worth as delivered 23 to 25 pesos per ton, the cost of extraction (*maquila*) last year was 10.50 per ton, and the profit 8 pesos per ton. The ore assays generally 1.2 kg. silver, equal to about 41 pesos per ton.

The bulk of the ore obtained from the mines of the Real del Monte Company is similar to that treated at the Hacienda La Union, although in the Corteza mine of that company there is produced the class of manganese ore called '*quemazones*,' on account of its black appearance. Such ore is not suitable for the process of amalgamation because of the loss of mercury, following upon the familiar reaction in which a mixture of salt, manganese dioxide, and sulphuric acid evolves the chlorine destructive to mercury. At the time of my visit, this ore from the Corteza mine went to the Hacienda de Loreto; it was a black silicious material containing 8% manganese dioxide. The treatment to be described has ceased lately, the

mill having been utilized to test the adaptability of the cyanide process to this class of ore. At first the idea was to erect a ball-mill, followed by a re-grinding tube, as at La Union, but later it was decided to install two sets of rolls, of the same dimensions and running at the same speed, the first pair for reducing the ore from 3 to ¾-inch and the other for grinding to 16 mesh; between the rolls there is a trommel, and thence the material goes to the tube-mill. Trouble was caused by the moisture in the ore, a coating being formed on the silex, requiring removal with a chisel.

I shall now describe the process for which the original plant was built; it was a modification of the Francke process, originally developed in Chile. On arrival, the ore passes through a Blake crusher and then it is fed to the rolls, which deliver it to a trommel provided with a 70-mesh screen; the undersize goes to the bins, while the oversize passes to a tube-mill (*cilindro remoledor*), also made by Krupp, where it is re-ground with flints (*piedras de chispa*) at the rate of about 40 tons per day. Then it joins the previous undersize in the bins. Next come four calcining furnaces, each with a capacity of 20 to 30 tons per day. The charge of 10 tons is given 1½ hours. Salt is added in the proportion of 18 kilograms per ton of ore. The calcined product drops below the furnace and is taken in wheelbarrows to the cooling-floor. Here it is shoveled into vats (*tinas de Bolivia*) where it becomes mixed, through the agency of revolving arms, with

cupric chloride ($CuCl_2$) and mercury. Copper plates placed along the sides of the vats catch any gold in the pulp. Each vat is 3 metres deep and 2½ m. in diameter. During the treatment, steam enters through the bottom. Three charges of nine tons each are treated per day. Then, after four hours of mixing, the pulp is discharged from these vats, through three openings at successive levels leading into pipes that empty in a mercury trap (*apuro*) outside. Here the silver amalgam is caught. The tailing passes on to two settlers, without further addition of mercury, the purpose being to arrest any amalgam escaping from the preceding operation. Below each settler there is an *apuro*, which finishes the treatment.

Only one shift of 12 hours (by day) is employed. Two men attend to each furnace; these also do the wheelbarrow work. Three men attend to the pans; in addition, there are two roustabouts and one foreman. Each charge is not followed by a clean-up; the amalgam is allowed to accumulate.

The mill was idle at the time of my visit; it is probable that there was a heavy loss through mineral which was ground fine in the tube and then pulled by the strong draft into the chimney of the calcining furnace. Also there is likely to have been loss of silver by volatilization as chloride.

The machinery is operated by electricity, and in contrast to this flagrant modernism is the shrine in the roaster-house, with its picture of the Virgin. In other parts of the establishment there are crosses,

decorated by withered flowers. Everywhere in the *hacienda* there is an exuberance of masonry; the works are enclosed by massive walls, like the ramparts of a fortress of the old-fashioned kind.

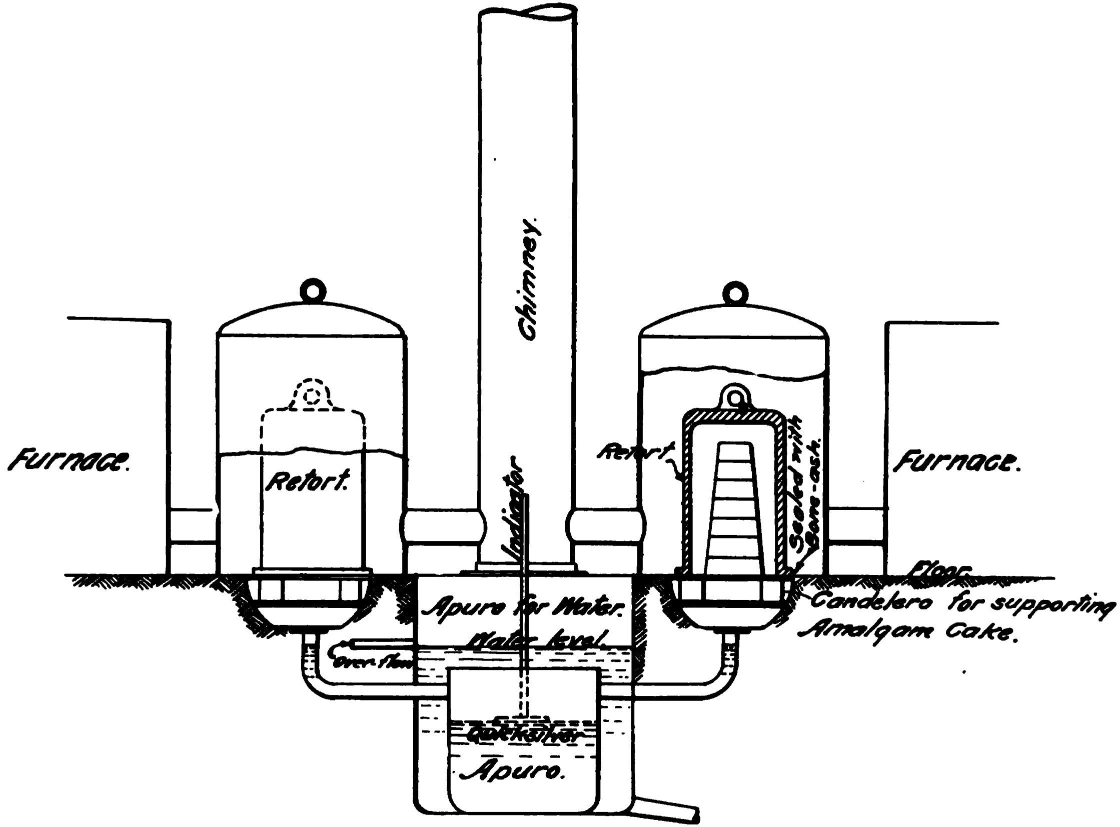
Such ore as does not contain manganese oxide, and comes from the other mines operated by the Real del Monte Company, undergoes direct concentration, followed by amalgamation. This quartz ore is reduced by two Blake crushers and then passes to 14 Chilean mills, which discharge through 80-mesh screens. The feeding is done by automatic (the Hendy Challenge) machines. From the Chilean mills the pulp goes to 32 Johnston vanners, which extract the pyrite, not only to get at the gold that is intimately associated with this pyrite, and to take out half the silver in the ore, but also with a view to simplifying the Patio process, which follows and which would otherwise need the addition of more chemicals. The 14 Chilean mills grind 800 to 900 tons per week; the crude ore contains 1 kilogram of silver to 5 or 6 grams of gold; the pyritic concentrate represents 4 to 4½ per cent of the crude ore; the richer concentrate, with 9 to 10 kg. silver and its proportionate amount of gold, is shipped to Germany, while the poorer, with 4 to 6 kg. silver, is sent to the smelters at Monterrey and Aguascalientes.

The tailing from the vanners goes to big ponds, where it settles to a thickness of 8 to 9 inches of pulp. The *camonero*, or horse with the drag, is employed to move the slime to the different rectangles in which

the mixing stage of the Patio process is carried out. There are 17 rectangles (50 metres wide and 80 m. long), for the treatment of as many charges or *tortas*, each being equal to 220 to 300 tons. The mixing is done, not in the old way by horses, but with a mechanical harrow, such as has been described in connection with the Hacienda Guadalupe. In this case also, it seemed to me that the mechanical mixer failed in its service; the material was too wet, the harrow omitted to turn the pulp over and simply passed through it, without causing aeration. Moreover, as the harrow cannot be made to scrape the floor, there always remains at the very bottom an inch or more of pulp, which is not moved and which, therefore, escapes metallurgical treatment. The clean-up was done as at the Hacienda Guadalupe, so that the description need not be repeated.

The retorting is worth noting. The bricks of amalgam are arranged in the form of a pyramid of about one ton weight standing in an iron pan, the bottom of which is perforated. A hood is then dropped over the amalgam; a flue from the furnace enters through an aperture near the base of the hood. The mercury, as it is distilled, passes out at the bottom into a stream of cold water, by which it is condensed. The ratio of mercury to silver in the amalgam is as 8 to 1.

At the Progreso mill, which was built by that representative American millman, M. P. Boss, there are 50 stamps, followed by four Kinkead mills; the lat-



FURNACE FOR RETORTING AMALGAM

Two Views of Men Operating the Planilla at Pachuca

ter is a machine for re-grinding. Then come two chemical mixers, 16 pans, and 4 settlers, followed by 4 New Standard and 6 Johnston concentrators.

Just outside the mill I saw the Mexican method of concentration by the *planilla*, or little plane. The material is heaped up at the head of an incline plane, 8 to 10 feet long, 4 to 4⅛ feet wide; the operator throws the water with a horn, by successive regular sweeps of his arm; at intervals he scoops up the material with a wooden shovel, and as the heading becomes cleaned (or concentrated) he moves fresh material to the top of the incline. Mexicans can be seen operating the *planilla* along the beds of streams that receive the tailing from the mills at Pachuca and Guanajuato, as the accompanying photographs show. The device resembles the 'tyes' or straight buddles employed for the treatment of slime in Cornwall.

Chapter 21

FIRST GLIMPSE OF GUANAJUATO—THE HISTORY OF LOCAL MINING—THE VETA MADRE AND ITS BONANZAS—RICH MINE-OWNERS—THE COUNT OF VALENCIANA—STORY OF THE CHURCH—DECADENCE OF THE DISTRICT.

T is uncomfortable to arrive at one's destination just before dawn, but sometimes the discomfort is not without compensation. Owing to the wretched train service between Mexico City and Guanajuato (406 kilometres or 252 miles), the traveler reaches Silao at 1 A. M. and then, changing to a branch railroad 14 miles long, he arrives at Marfil at 3 A. M., whence a horse-car bears him to Guanajuato, a distance of four miles and occupying an hour. The car is pulled by mules, at a sharp trot, along a winding tramroad that follows the bottom of a ravine; there are glimpses of high walls, dark archways, and silent courtyards, an occasional hooded figure comes within the rays of the feeble lamp at the front of the car, other lights are infrequent; soon the tram penetrates a thickly built town, the mules awaken echoes as they scramble over the cobbles; the reverberations are lost in narrow alleys, but there is no sign of life, save the

tired watchman who blows his whistle to prove himself awake and to prevent the other watchmen from falling asleep—incidentally telling any prowler just where to avoid him. The car goes up a steep gradient, almost brushing the walls that look down on either side, around sharp turns that threaten a capsize, over a narrow bridge and along a stream flanked by rustling trees. The journey is over. A friend conducts me to a lofty wall, a door opens, we are in a moonlit *patio*, in front of a white colonnade, in that light as poetic as the moonlight itself, the effect of which is heightened by a sound as of surf borne inland from the shore; it seemed the voice of the distant sea, but it was the muffled roar of a stamp-mill. However, that rhythmic swell served to put me to sleep, deeply grateful for a little rest after the tiresome travel of the night. This was part of the compensation, but the best of it came on awakening three hours later.

It was a sunny morning, with all the coolness of the highlands and all the fragrance of the tropics; going on the portico, I found myself overlooking a lawn behind which extended an array of steel vats indicative of a cyanide plant; to the right were the white-washed houses occupied by offices, and to the left rose a loftier building—audibly, a stamp-mill. The whole foreground was surrounded by a wall on which the sunlight played gladly. Beyond were low roofs and trees, rising on hillslopes, partly under cultivation and leading to a brown ridge whose clear-cut edge was silhouetted against the blue of a perfect sky.

It was the Hacienda San Francisco de Pastita, an old Mexican reduction works, now transformed to modern methods, it was an island of Anglo-Celtic energy in the midst of an old Spanish mining centre, and the spirit of the men and the machinery of this new mill of the Sirena mine was to the old era represented by the decrepit town outside its walls as the invigorating sunshine of this bright morning to the dark weariness of my experience during the night that was past.

Guanajuato, in the State of the same name, is a city of 50,000 people, situated at an altitude of 6,600 feet among the foothills of the Sierra de Santa Rosa. The air is dry and clear, colors are vivid, lines are defined, and the sunlight is brilliant. The town is not without character, for it is adorned by many churches and other impressive buildings; it lies ensconced among terraced gardens and brown hills, on the higher slopes of which stand the battlemented enclosures and picturesque churches of historic mines. Their story is worth the telling.[30]

The history of Guanajuato begins in 1526, six years after the Spanish Conquest, when the mineral wealth of Mexico was being eagerly sought out by the hardy *conquistadores*. To the north, the mines of Zacatecas and San Luis Potosi had been uncovered; the road to them, from Mexico City, passed near the site of Guanajuato, but in those days it was dangerous to depart from the highway, for the natives, the

[30] And in the telling of it, I am indebted for many of my data to Capt. W. Murdoch Wiley, who has studied the records.

Chicemecas, were unfriendly. A fort was built at Santa Ana, and this became the first European settlement in the region. Prospecting became more practicable, but no mineral discovery of importance followed, until 1548, when the silver mine of San Bernabé was discovered at La Luz, six miles from the Guanajuato of today. Two years later rich ore was found on the hills adjacent to the present city; the Rayas mine being started by a Spaniard of that name. The document that registered this fact is the oldest in the archives of the Court of Mines at Guanajuato. It was not until nine years later that the work done at the Rayas and Mellado mines led to the recognition of the mother vein, *la Veta Madre*. The ore was mined for a width of 100 feet, so wide indeed as to postpone further exploration along the course of the lode. But the ore found by the Mellado shaft, in 1559, suggested the idea of continuity and caused an extension of activity, so that it was not long before mining operations were under way from the Tepeyac to the Sirena workings. To those of us who regard the discovery of the Comstock, less than 50 years ago, or even the event at Sutter's Mill, 58 years ago, as a historic event, it is worth noting that the happenings briefly chronicled in the foregoing lines occurred before 1600—before the first settlement of Virginia, shortly after the sailor captains of Elizabeth had swept the Spaniards off the seas, and just about the period when Shakespeare and Bacon were busy preparing documents of controverted authorship.

By this time the population of the town had grown to 4,000, and it continued to increase as villages sprang up around the individual mines. In 1619 the town was granted a patent, becoming dignified by the name of Villa Real de Guanajuato. This was a year before the landing of the Pilgrim Fathers at Plymouth.

The industry grew; amalgamation was introduced from Pachuca, the Patio process being first employed at the Hacienda de Duran, just below the Rayas mine. The best selected ore was smelted on the spot and, considering the high grade of it, the slag was surprisingly clean, for the remains of old smelter dumps below the Rayas and Cata have been found to assay only two ounces of silver per ton. Forced labor, of course, was employed, and two proclamations bear testimony to the brutality of it, for one of them prohibited the indiscriminate sale of Indians and the other forbade the branding of a slave in the face.

Within a century, that is, by 1700, the population was quadrupled and the area of the camp was doubled. Immigration was slow, for Spain was a long way off in those days of uncertain sea voyages; the transport of supplies was both laborious and hazardous, the whole European population of Mexico was still meagre, and mining methods were as yet primitive. But the discovery of gunpowder and its application to mining, the introduction of pumps and the accumulation of wealth among the mine owners,

all tended to enlarge the scale of operations until Guanajuato, toward the end of the 18th century, became one of the great mining centres of the New World.

The big mine owners won such wealth that, like their modern successors in Nevada and Montana, they became legislators and were given seats in high places; they were granted titles of nobility and enlivened the ranks of Spanish aristocracy. José de Sardañeta was created Marquis of Rayas; Francisco Mathias, the owner of the Cata and Secho mines, became Marquis of San Clemente and Viscount of Duarte, while Antonio Obregon, the discoverer of the Valenciana, became Count of that name. It was a great day for these mine operators. They were consulted in affairs of State, just as nowadays men who contribute to campaign funds are likely to possess what Mr. Mike O'Flaherty terms 'infloo-ence'; they posed as Providence to the poor people, for when times were hard and the corn crop was a failure, they provided work for the needy and saved them from starvation. It is said that the big galleries and comfortable cross-cuts, large enough for the passage of a broad-gauge locomotive, that surprise the mining engineer when he first visits Guanajuato, are the evidence of work carried out with such charitable intent.

When an unusual bonanza was struck, the fortunate miner built a shrine or even a church, in token of gratitude to his tutelary saint. Thus one Sardañeta advanced an adit so as to cut the Santa Anita

ore-shoot on its dip, but failing to reach this point before he died, he told his son to continue the good work. He did, and found the bonanza of Santa Rosa, which made the Rayas mine famous. This Sardañeta became Marquis of Rayas and erected the monumental buildings whose flying buttresses and sculptured portal, surmounted by the figure of the archangel Michael, are today the glory of the San Miguel shaft-house.

The church of Valenciana is another such memorial to successful prospecting. This edifice was consecrated in 1778; though badly cracked in many places and doomed to destruction, its fine harmonious façade in carved *cantera* was rendered doubly impressive when I saw it at the end of a day's investigation of the old mines, and, mindful of a most romantic chapter of mining history, watched the shafts of sunlight suffuse the old church-front with a glory richer than the treasure vault of silver that it commemorated. The church was built by Antonio Obregon, a Spanish miner, who discovered a great orebody north of the Cata mine, in ground that had long been held to be barren. He had thought otherwise and prospected for three years, until penniless. Then a merchant of Guanajuato provided some funds, until he too was bankrupt. Others were persuaded to share in the venture, only to lose their money, until Obregon won the name of *el tonto* (the fool) *de Valenciana.* But his justification came at the end of seven years of persevering work, when he broke into the biggest

The Flying Buttresses of San Miguel de Rayas

In the Courtyard of the Rayas Mine

bonanza ever found on the Veta Madre. It was much more than his fondest expectation, for, while the Tepeyac had been worked in a desultory way from 1590 and the outcrop of that vein in the Valenciana ground has yielded some ore, it is doubtful whether any such ordinary body of mineral could have repaid the long and expensive search made by Obregon and his backers. In a few months all the expenses of years were repaid and eventually Obregon became, the chronicle says, the richest man in the world, at that time. The immediate origin of the church is told thus: On the ground near the mine, Obregon marked out an irregular quadrangle within which the miners were told to place a handful of rich ore, which each man was allowed, for this exceptional purpose, to bring out of the mine. It was a custom that recognized the innate tendency of the miner to purloin a little—a specimen or a sample—of the rich ore that he was helping to extract; and by requiring his men to donate that larcenous portion of mineral for the benefit of Holy Church, Obregon was finally able to do a great deed without unduly taxing his own receipts. The quadrangular area as marked was eventually covered three feet thick with rich ore; this was sold and the proceeds of it were employed to build the church. It was begun in 1765 and finished in 1785; it is said to have cost $1,000,000, which was about equivalent to the annual income of Obregon. He made gifts to the Crown and, becoming the wealthiest subject of Spain, he was made Count of

Valenciana. This was at the time of the American revolution, and since then we have had many a Monte Cristo among mining adventurers, a motley crew of ill-balanced men, from vulgar spendthrifts like Tabor and Barnato to great-minded builders of empire like Cecil Rhodes and Alfred Beit.

Chapter 22

GUANAJUATO AT ITS HEIGHT — DEEP MINING — VISIT OF HUMBOLDT—DECADENCE—LA LUZ—THE REVIVAL—AN AMERICAN INVASION—THE STORY OF MODERN PROGRESS.

AT the end of the 18th century the mines of Guanajuato were the foremost of their kind. It was then that the Valenciana shaft was sunk to 1,800 feet, and it is still the deepest in the district. This work, done by Obregon, was completed in 1785 at a fabulous expense. It is said to have cost a million, though even this expenditure becomes small relatively to that of the Combination shaft, sunk on the Comstock lode, in 1881; this was 3,100 feet deep and cost $6,000,000. However, the cost of the big shaft of the Valenciana was offset by an extraordinary production, stated at 300,000,000 dollars, most of it extracted during the last half of the 18th century. This figure corresponds to the total output of the Comstock up to the time when the lower workings were abandoned, in 1884. On August 20, 1804, the King's tax, amounting to the sum of 2,648,866 dollars was paid. As this represented one-fifth of the yield for a period of five years, it serves to substantiate even the

extraordinary statistics of these old mines. The other mines on the Veta Madre and those on the La Luz veins also produced enormously at this period, so that the population of the district at the beginning of the 19th century had increased to 100,000. This was the time of Humboldt's visit. He says that "the whole vein (the Veta Madre) of Guanaxuato[21] may be estimated at four ounces of silver per *quintal* of minerals." As a *quintal* is 100 pounds, this means ore averaging 80 oz. per ton of 2,000 pounds.

Then came the long years of the revolution against Spanish domination. In 1810, when at the height of her prosperity as a mining centre, Guanajuato was attacked by the Republican forces under Miguel Hidalgo, a priest, who became the hero of the Mexican war of independence. There was desperate fighting and the city was captured. The entire fabric of government and of business went to pieces. The warring factions made forced loans on the mines, horses and provisions were wantonly seized, life became insecure, so that mining operations were discouraged and all work of importance was discontinued. Deep work ceased entirely, no shafts were sunk, and the production of ore was reduced to infrequent shipments taken from supporting pillars and from the sides of old stopes. Even such decadent mining soon became insignificant as the miners were driven toward the surface by the slowly rising water.

[21] It is always spelled with an x in Humboldt's memoirs.

Looking Down the Main Street of Guanajuato

The City of Guanajuato

It was at this period of general lawlessness that the heavy walls with watch-towers were built around the mines, until every property of consequence had the look of a fortress. Similar protection was given to the reduction works, which became fortified enclosures, for the *patios* were frequently robbed of their clean-up by roving bands belonging to both factions, which made the necessities of their organization an excuse for a general system of pillage and murder. The battlemented ruins that survive in the vicinity of Guanajuato are eloquent of this period of lawlessness and afford today a picturesque setting to mines already romantic through their earlier traditions.

Twelve years elapsed before the Spanish rule ended in the crowning of Iturbide as the first Mexican Emperor, at Mexico City, on July 21, 1822. During the interval the population of Guanajuato dwindled to 20,000 and mining almost ceased. With the restoration of order, the mine-owners set to work to rehabilitate their properties. Among the most enterprising was Don Lucas Alaman, who represented the new Republic at the Court of St. James, and was an enthusiastic believer in the mineral wealth of Guanajuato. He interested English capitalists in his schemes, with the result that two large companies were formed, the United Mexican Mining Association and the Anglo-Mexican Mining Company. They acquired several of the biggest mines on the Veta Madre, besides others of the Sierra and La Luz systems. The old workings were unwatered and the

mills were renovated. But it was not smooth sailing for these English companies, there were periodical local insurrections, life and property were still insecure, and mining was attended by many interruptions; for example, in 1832, one Ariste, at the head of a 'regenerating army,' or *ejercito regeneradoro*, swooped down on the Rayas mine, then the property of the United Mexican Co. and lifted silver and corn to the value of 26,000 pesos.

The mines of La Luz were in bonanza in 1842 and for many years after, so that Guanajuato itself became less important, but twenty years later Francisco Glennie took charge of the Rul estate and by his skill he made these mines on the Veta Madre more productive than they had been at any time since the palmy days at the close of the eighteenth century. The Valenciana was unwatered to the bottom at 1,800 feet and a new orebody was discovered in the Merced[22] vein. At the same time Glennie developed the Cata mine and found the rich Juanita[22] vein. When he became invalided, in 1890, another period of depression ensued at Guanajuato. All the company work at the Valenciana was stopped and the water was allowed to rise. At the Cata, the water was kept down, but here, as at the Valenciana, the workings were handed over to the tender mercies of the *buscones*. These are 'tributers' on a small scale; they take a lease from week to week without any writ-

[22] These were special segregations of rich ore in the Mother Lode.

ten contract and divide the ore they get with the mine-owner, who provides the tools, powder, and blacksmith. On each Saturday morning the *buscon* sorts his ore, arranging it in two equal piles, of which the foreman takes his choice on behalf of the owners of the mine. Of course, the *buscon* cannot afford to explore, he does no 'dead work'; and as he moves no more waste than is necessary, the workings soon become choked with refuse. He nibbles at every pillar left to support the old stopes, and causes caving that will close the mine or portions of it, permanently.

And so mining came down to a dreary unprogressive level, with no new work and no fresh discoveries of ore, until, in 1898, another revival was inaugurated by the enterprise of a few Americans. In that year the Guanajuato Consolidated Mining & Milling Company secured the Sirena mine and erected a modern mill, under the direction of Mr. M. E. MacDonald, assisted subsequently by his brother, Mr. Bernard MacDonald.

In 1902 the Guanajuato Power & Electric Company was formed by a group of mining men at Colorado Springs, on the initiative of Mr. Leonard F. Curtis; he was ably supported by Messrs. George Bryant and George W. McElhiney, to whose financial ability are due several of the most important enterprises in the district. As fuel of any kind was very expensive, the introduction of power at a reasonable price was an important step in the progress of mining. This was accomplished in November, 1904.

The electric energy now used at every large mine in the Guanajuato district is obtained from the river Duero, in the State of Michoacan, 101 miles distant. This power at 185 pesos per h.p. year[38] replaced wood at 8 to 10 pesos per metric ton and stone coal, from Las Esperanzas, in Coahuila, at 20 to 24 pesos, delivered.

The next enterprise of importance to be started was the Guanajuato Reduction & Mines Company. The history of the mines that it acquired has been mentioned; they included the property originally belonging to Obregon, the discoverer of the Valenciana, and from his descendants by intermarriage they had passed to the noble family of Rul. In 1860 the Señora Perez Galvez, then head of the house of Rul, began a clever campaign, the purpose of which was to obtain *avios* or perpetual leases on these mines, including the Valenciana, Cata, Tepiac, and Mellado. By the *avio* she was able to charge all expenditures against the mines, crediting them with the money received from the sale of ore; by building large works or *haciendas*, she made contracts with herself to purchase the output of ore, deducting high rates for treatment and mixing the rich with the poor ore, so that the expenses of mining were always in excess and steadily increased the debt against the mines, while permitting of handsome profits at the *haciendas*. The options to these contracts or *avios* were acquired by Messrs.

[38] This is the average price. The lowest price in the district today is $60 per h.p. year.

Bryant & McElhiney, and transferred by them to the Guanajuato Reduction & Mines Co., which finally bought them outright. According to Mexican law, if at any time the mines get into bonanza, so as to make big profits from the sale of ore, the lessee has the right to take all such profits, without any division with the owners, until the entire accumulated debt—about six million pesos—is paid, thereafter dividing the further profits according to the terms specified in the lease; in plain English, the original ownership is a legal figment. Besides acquiring these old contracts, the promoters mentioned had the foresight to 'denounce' or 'locate' claims covering the dip of all the important properties on this part of the Veta Madre; that is, they secured the 'deep levels.' Finally, after expert examinations and reports had been made by such men as Carlos Van Law, Robert T. Hill, and Louis Noble, these properties and all their rights passed under the control of the Guanajuato Reduction & Mines Co., in November, 1904.

Since then other ventures have been organized and started, but their story is in process of making and must be left to a later record.

While the peso today is worth about half of a dollar, before the demonetization of silver they were about equal, for each contained about an ounce of silver.

Chapter 23

VISIT TO THE OLD MINES—A CAVALCADE—THE BUSTOS PLANT—MECHANICAL DEVICES AGAINST MANUAL LABOR—THE MOTHER LODE—SAN MIGUEL DE RAYAS.

N the morning of November 2, a party was made to visit the old mines of the Veta Madre. We formed an imposing cavalcade, for it is the custom in Mexico for each horseman to be accompanied by a *mozo*, who serves as groom on ordinary occasions, and is a courier and general servant when going across country to the mines at a distance. These men wear the wide-brimmed *sombrero*, fancy leggings, and big spurs, so that they are picturesque if nothing else, and on an occasion of pleasure such as this was, they gave a touch of gaiety to a group of horsemen, most of whom were as properly accoutred as in Chapultepec or Central Park. There were ten of us, and eight *mozos*, so that when we clattered down the narrow cobble-paved alleys of the old Mexican town, we made noise enough for a regiment, scattering careless wayfarers and awakening echoes under arches that had seen many invasions much less peaceable. The well-bred Mexican is a splendid horseman, but the inhabitants of such a town as Guanajuato are, of

Among Friends at Guanajuato

G. W. Bryant, Bernard MacDonald, T. A. Rickard, F. J. Hobson, D. J. Hutton, C. W. Van Law, M. E. MacDonald, Norman Rowe.

Steel Ore-Bins and Battery Foundations of the Bustos Mill

course, content to go afoot, so that accompanied as I was by a group of engineers and metallurgists, it occurred to me that there was a simile to be snatched from the scene, the technical man being the fellow on horseback, progressing confidently (usually with less noise), while the rest of the world is content perforce to go on foot. Well, my friends rode several hobbies, not to mention spirited steeds; one of them was the application of the cyanide process to silver ores; and their horsemanship was good either way. On arrival at the lower end of the town, I was shown the Hacienda de Bustos, where the Guanajuato Reduction & Mines Company is remodeling an old reduction works to the needs of a modern equipment, as the accompanying photograph will illustrate. This *hacienda* is about a hundred years old; in pulling down the walls to make room for the concentrator floor, there was found a system of older unconformable foundations, and in the angle made by two walls of ancient date, the workmen unearthed half a dozen complete skeletons, with a bullet hole in each skull, and so placed as to indicate that the originals were pistoled while lying down. However, this gruesome find did not hold our attention long, for the foundations of the new stamp-batteries and the steel framing of the ore-bins afforded more cheerful subject for thought.

In the erection of the Bustos plant, bedrock was everywhere available, and the heavy masonry walls were built cheaply by Mexican labor, which is par-

ticularly skilled in such work. Each stamp weighs 1,050 pounds. The mortars are of El Oro type and weigh 9,000 pounds; they rest upon massive concrete blocks laid in Dyckerhoff cement. The concentrator room is spacious, being covered by a well-designed roof-truss of steel construction. The tailing from the Wilfley tables runs into a concrete launder, which extends down the longer axis of the concentrator room to the centre of it, delivering its contents to a tunnel at right angles and thence to the cyanide annex. While the plant was in course of construction, a 5-stamp battery, with its cyanide annex complete, was being employed for testing the various ores destined to be delivered to the works when finished. Even when the 80 stamps are at work, this small addition will be kept in service, for experimental purposes. In the concentration department of this testing plant there is a Wilfley table, a Gilpin county bumper, and an Overstrom table. After being crushed under the stamps, the pulp passes over one of the three machines just mentioned and then to a sump, whence it is pumped 60 feet to cone-separators. The sand undergoes percolation in vats 8 feet deep and 8 feet diameter, provided with the Butters hydraulic distributor. The slime is agitated in vats 9 feet deep and 8 feet diameter; one vat using the Hobson aero-mechanical agitator and the other a Butters pump with mechanical stirrers. Thus the testing plant is designed throughout to duplicate the conditions under which the big mill is to be operated.

The Gateway of the Rayas Mine

The Ruins of the San Miguel de Rayas Mine

The Bustos mill is planned so that it can be doubled conveniently; in fact, excavations for that purpose were under way at the time of my visit. A sufficient space will be cleared at the back of the existing plant to allow of the erection of a second row of 80 stamps on the other side of the bins. A concentrator room, identical with the existing one, will be added, so as to make the plant a 160-stamp mill of back-to-back construction.

Owing to the high price of American lumber when delivered at Guanajuato, and the poor quality of the Mexican material, it is considered economical to use steel. The skeleton of the bin is of 15-inch channels placed back-to-back in bents that are on approximately 6-foot centres, the vertical channel posts being tied together at the bin-floor level by two 15-inch channels, which are braced from the feet of the posts by inclined struts composed of four 5 by 3½ by ⅜-inch latticed angles. The thrust that these inclined struts carry to the feet of the posts is taken by two 8-inch channels acting as a tie between the feet of the posts, thus trussing the whole and making the strains on the masonry wholly vertical. As the weight in the bin is about 2,500 tons, exclusive of the bin itself, the feet of the columns are supported upon a grillage of six 5-inch I-beams, two feet long, held together by plates riveted to the top and bottoms. This rests directly upon the masonry. All the bents are braced together longitudinally at the top and floor-level of the bin by 8-inch channels and heavy

angles; at the ends of the bin the outward thrust upon the bents is taken by a truss-member at the top of the bin. The bents themselves are tied together at the top by ¾-inch plates 4 inches wide, riveted between the channel-beams to the posts. Within this skeleton is a lining of plank, 4 inches thick in the bottom courses, with an inner sheathing of 2-inch plank having the grain vertical. The bin has a flat bottom supported on 4 by 14-inch joists on 12-inch centres, carried upon horizontal members of the steel bents before mentioned, on the top of which is laid a 3-inch plank covered by a 2-inch lining. The entire construction does credit to the manager, Mr. Carlos W. Van Law.

While we examined the mill, an interesting discussion arose regarding the comparative value of the mechanical conveyor. Cars were advocated as economical because the cost of power alone (apart from repairs to the conveyor, maintenance, and interest on capital) exceeds the expenditure for labor when employing cars *plus* human labor. A conveyor requiring 7 h.p. at $7 per h.p. month is equivalent to, say, $50 or 100 pesos per month. The same work can be done by two *peones* at 50 centavos per day, equivalent to 30 pesos per month. In case a *peon* wears out, you can get another without absorption of capital! But alas for such calculations, the *peon* does not work on feast days. There is a great advantage in employing machinery that goes forward without any stops. For in Mexico there are 25 *fiestas*

per annum that are rigidly observed, besides Sunday and San Lunas (or St. Monday—sacred to sobering observance), so that there are at least 75 days of interruption in a year, and wherever laborers are not plentiful, this feature must be taken into account. On the other hand, if one has a bin capable of holding a ten days' supply of ore for the entire plant—as is the case at the Bustos mill—the bad effect of two or three days of *fiesta* is obviated. Of course, where a car-track is impracticable or where elevating is required, the conveyor holds the field—and that is often.

Leaving the Hacienda de Bustos, we rode up a ravine leading to the mines on the great lode of Guanajuato, called the *Veta Madre*, a term which in the guise of 'Mother Lode' has also been applied to the main vein-system of California. In the State of the Argonauts it refers to a general zone or belt several miles wide and 300 miles long, but at Guanajuato it defines a distinct lode-channel about 600 feet wide and seven miles long. At the foot of the hill on which stands the Rayas mine, the Veta Madre is crossed by the Cañon de Zapote, and a natural section of the big outcrop is visible. The lode consists here of eight feet of silicified breccia; on the foot-wall, exposed in the bed of the stream, there is a quartz vein traversed by black streaks of argentite that dip at 45°; and under this ore comes brecciated schist cemented by quartz, the latter diminishing until the schist exhibits a ramification (*ramillo*) of stringers,

the dominant members of which are parallel to the foot-wall. Beyond this point, the quartz continues to decrease, and on the farther side of the stream the schist appears in the regular laminæ to which it owes its name of *hoja de libro*, or book-leaves. This is the main foot-wall country.

Remounting our horses, we returned down the cañon, soon reaching the Rayas church, a beautiful remnant of the loving architecture that the Spaniard lavished even on his mines. In these churches are found all sorts of queer pictures celebrating the thankfulness of the donor for deliverance from various perils. In them the miner testified to the danger of his calling, by the tribute offered to his particular saint.

Ascending the hillside overlooking the church and its environing buildings, we turned to look on the crumbling walls of an old *hacienda*, which we had failed to notice as we rode past it. The walled enclosures seem inadequate for protection, and yet they served their purpose before long-range rifle practice was developed. Until about twenty-five years ago, brigandage was so rife in this, as in other parts, of Mexico, that the *haciendas* or reduction works were periodically 'held up' by outlaws, particularly in outlying districts. As regards Guanajuato, their special nest was at El Capulin, on the road between Silao and Marfil. They terrorized the country, and despite occasional raids from the military, who drove them into the hills, the bandits would return after a short

interval, to resume their depredations. Finally, in 1883, the State Government sent a body of mounted police to attack them. Sixty men were captured, placed against a wall, and shot. El Capulin was completely destroyed; not a hut was left to mark the spot. That ended the business.

Passing close to the flying buttresses of the magnificent walls that enclose the San Miguel shaft of the Rayas mine, we entered the old enclosure. A suggestion of the appearance of this architectural survival is presented by the photograph facing page 167.

A little farther and we entered the courtyard of the Rayas shaft, one of the four great openings on the Veta Madre. This one is octagonal in shape, and 38 feet in diameter. The depth is 1,400 feet. Why these shafts were so big and the manner in which they were operated, will be told in the sequel. They make even the most self-confident American miner realize that his science did not begin at Virginia City, nor was it born in Colorado. The Rayas was sunk by the Spaniards in 1850, while the Valenciana shaft is a hundred years old, and yet one can read in the *Mining and Scientific Press* of forty years ago that there was jubilation on the Comstock when the Ophir shaft reached 400 feet, and that doubts were entertained whether there would be machinery able to cope with any greater depth. Yet eventually the men of Nevada went down 3,250 feet.

Chapter 24

A GRAND VIEW—REMINDERS OF A FORMER TIME—ENGLISH ENTERPRISE.

ROM the stone balcony or *mirador* of the Rayas mine, there is a splendid view of the country around Guanajuato. I shall try to describe it.

In the distance to the left, the bold ridge of La Bufa, a scarp of rhyolite tuff, is silhouetted against the clear blue sky. Under the overhanging brows of these cliffs and protected from the weather, there are figures of heroic size painted on the rock; they represent a red devil and his retinue tempting the Christ. In the cavern adjoining these are several paintings of St. Ignacio and the Virgin, done in color with as much skill as the similar work to be seen in the churches. This mountain top—from which may be seen Guanajuato, Silao, Leon, and the wide expanse of the rich Bajio—was supposed to suggest that from which El Salvador was shown the kingdoms of this world and their glory, in the great temptation. Lower down, near the talus slope, the other temptations are depicted in a crude way. It is not said that the riches of the Veta Madre were

offered; they have tempted many men to their undoing during the last two hundred years.

On the rounded foothills that extend from the base of La Bufa begins the residence portion of Guanajuato; it is called La Presa, because of its dominant feature, a big dam with an encircling park. Seen from a distance, there is a gleam of pink walls among cedars and the tops of some church-towers; then the crest of a ridge intervenes. At the foot of this and in the *cañada* below the Rayas, there is a cluster of brown ruins, La Duran, the oldest *hacienda de beneficio* in Guanajuato, and contemporaneous with the discovery of the Patio process, in 1557. A hundred yards below it, the bed of the stream is crossed by the slender line of an aqueduct, which now serves to carry the pipe-line that brings the water-supply of the town. The six pillars are capped by a series of broad keystones, which do duty as arches. This is a characteristic type of Mexican architecture.[24] Below the aqueduct, the *cañada* turns to the right and becomes fringed by Peruvian pepper trees, and beyond them is the big hollow in which the town of Guanajuato lies huddled—a multitudinous complex of walls—pink, yellow, and white—with red Moorish campaniles. The narrow river-bed is marked by a con-

[24] The 'flat arch' is held by some to be the oldest and simplest expedient for supporting a structure; it is supposed to have originated from the big stone placed over a doorway in the days before the idea of the true arch was developed. Other engineers, for instance, Mr. Carlos Van Law, are of the opinion that the flat arch was a development from the true arch, and that, in form and principle, it is the real origin of our modern 'invention' of fire-proof floor construction with its so-called arch-tiles.

gestion of brown walls; on the onlooking slopes there is a decrease in the density of building and an increase of verdure, until the top of the ridges is reached, where there are no dwellings, but only the dark red earth of the cornfields, defined by hedges of organ cactus. Surrounding the town and overlooking it, are golden brown hills, with contours deeply eroded and steep ravines, the culminating point being the cone of Cubilete. The broken sky-line is carved in diabase, and the nearer slopes are eroded in the conglomerate that lies on the flanks of the main ridge.

In front, beyond the huddled habitations of man and the brown hills, crossed by the traveling shadows of clouds that fleck the vivid blue of the sky, stretches the purple interval that marks the Bajio, a great valley along which runs the Mexican Central—an unromantic railroad, with slow trains, sloppy Chinese cooking, and a most distressing service. Beyond it, like the good things promised on the other side of this vale of tears, is the blue line of the Cordilleras, throbbing with soft enchantment and pulsating with the romance of mining that shall not die.

When luncheon was over we left the *mirador*, and in doing so passed through the remains of a pretty garden. It seemed strange to see the old-fashioned gilly-flower, rose bushes, and violets among these mine buildings. They had a story to tell of the Englishmen who planted them. There was a time, from 1824 to 1850, when English capital irrigated the mining camps of Mexico, and among them Guanajuato.

Owing to the costly methods of operation, the attempt to employ only the comparatively expensive imported white labor, and the lack of experience in treating the silicious silver ores, these early efforts were generally unprofitable, although with their characteristic dogged determination, the English companies continued to operate the mines, with steadily diminishing intensity, for many years. While active work on any important mine ceased fifty years ago, they held on to the San Cayetano until within a few months, when that property was transferred by the United Mexican Mines Association, Ltd., organized in 1814, to a new American company. Between the English period, already defined, and the present American dispensation, there was a good deal of work done under Mexican companies, although these lacked the enterprise of the heroic days at the very beginning of the nineteenth century.

Chapter 25

THE GREAT SHAFTS OF THE VETA MADRE—THE RAYAS — THE CATA — THE TIRO GENERAL — WHAT BRYAN SAID OF IT—HOW IT WAS UNWATERED—A WONDERFUL SPECTACLE.

HE four great shafts on the Veta Madre are the Rayas, the Cata, and the two pits of the Valenciana, namely, those of San José and Guadalupe.

The Rayas is octagonal and 38 feet in diameter, with a depth of 1,400 feet. Among the old machinery to be seen near-by is a Cornish hoisting engine of 1835 built by Harvey & Co., at Hayle, Cornwall; alongside are two Lancashire boilers. In another building is a first-motion hoist built by the Union Iron Works, of San Francisco, in 1866; it is one of the best of the old style, with jaw-brake and flat wire-ropes. The head-frame is built with timber struts footed in cemented masonry. This was erected in 1887, when the Rayas mine was unwatered. But there is a suggestion of methods used long before even this old machinery was set to work; the sites of the horse-whims used by the Mexicans is marked by a tablet inscribed to the patron saint of each operator.

One, for instance, reads "San Francisco. Nov. 1, 1820."

The Cata shaft is 280 metres, or about 925 feet, deep and 20 feet wide. At the collar, and for 50 feet down, it is octagonal, with sides of masonry. I went down in a cage running on wire-rope guides, which gave one a feeling of detachment, for in places, below the portion that is lined with masonry, the pit is 30 to 40 feet wide. A native boy held a torch to illuminate the distant sides of the shaft. The torch used in the mines is worth describing: It is called a *mecha* and consists of 40 native candles, made of tallow and yarn, which are pounded into a mass and wrapped in a cloth with wood splints to stiffen it. Outside of this is a wrapping of *riata* or twine, obtained from the *maguey* plant. The torch is two feet long and 2½ inches thick; it is wetted outside, so that the tallow will congeal as it drips. By the light of it, when we reached the bottom of the shaft, we saw the Aldrich quintuplex pump, made by the Allentown Rolling Mills, Pennsylvania. It consists of a battery of five vertical plungers, all the five cranks inside, with two post-bearings outside. This pump is said to be doing good work, lifting 300 gallons per minute to the drainage adit, 880 feet overhead.

The San José shaft was also known as the *tiro general* or general shaft of the Valenciana; it has been mentioned already in recounting the early history of Guanajuato. It is an impressive hole. There is none like it. It is octagonal, 33 feet in diameter and lined

with masonry for 100 feet. The bottom is at 525 metres or 1,730 feet. Water-level stood at 198 metres or 650 feet at the time of my visit. This is the shaft of which it was truly said—among others, so I was informed, by Robert Bunsen at Leadville in 1881—that a man can read his paper at the bottom by the light of the sun, because here in the tropics during the summer solstice the sun for two weeks is vertically overhead. Early in July, the mist caused by the sun's heat striking directly on the water at the bottom of the shaft, causes a beautiful rainbow every day at noon. This is the shaft also of which William Jennings Bryan—who visited Mexico after his first silver campaign and was royally entertained—said, that he had never before seen a hole big enough and deep enough to bury the gold standard. But he said nothing at all about the shallowness of the oratory of the river Platte! However deep the shaft may be, it will be filled up some day unless tourists are forbidden a near approach. From time out of mind it has been deemed great sport to throw stones down this vast pit and listen to the reverberations. I offered my tribute to the Tiro General. First one hears the sound of rushing wind—the echo of the passage of the stone through the air; then there comes a roar as it strikes the side of the shaft, and this is followed by a crash as it hits the water. (In the light of later events, here in San Francisco, I can tell my friends at Guanajuato that these sounds resemble the on-

The Great Shaft of the Valenciana,
Looking Down; the Sun Is Reflected
by the Water at the Bottom

Bridge over the Guanajuato River, near La Presa
La Bufa in the Background

coming of an earthquake, to anyone living near the actual line of faulting.)

The shaft is octagonal, this shape being due to the method of hoisting prevailing at the time it was sunk. Around it, at a radius of 150 feet, can still be seen the ruined gables of the eight houses, each of which contained a *malacate* or horse-whim. A *malacate* is said by the Mexicans to be operated by *fuerza de sangre* or force of blood, as compared to the *fuerza de vapor* or steam-hoist. The typical *malacate* employed in this work was usually a vertical drum of oak or *mesquite*, from 12 to 16 feet in diameter and 12 to 14 feet high, with a wooden central axis supported on iron gudgeons, top and bottom. The lower end of this drum was about three feet off the ground and to it were fixed four heavy *mesquite* sweeps of 15-ft. radius. To the end of each sweep were harnessed four horses, in crude rawhide harness, driven by a boy (seated on each sweep) at a gallop around the circle. Originally a hemp rope—later, a steel cable—was wound eight or ten turns around the drum, both ends depending in the shaft and hoisting in balance. The trip completed, the horses were reversed on the sweep and the return trip commenced. As, with the depths worked, the empty bucket, plus rope, considerably overbalanced the load when the latter neared the surface, the driving boys usually had to hop down from their perch toward the end of each trip and restrain the motion of the drum by holding

back while the horses were turned out to one side and disconnected, all without stopping the hoisting. There was no brake on any of these old *malacates;* when it was desired to hold them at any given point, an attachment was made to the nearest fixed timber.

Rawhide buckets, made by sewing together two bulls' hides, were used exclusively. In these, both ore and water were hoisted, and the experience of American engineers has proved that for taking water out of shafts in sinking, the rawhide is better than anything else, being lighter and easier to handle in proportion to the quantity of water raised than any other form of bailer.

Over the shaft stands the shaky head-frame built in 1872 during the unwatering of the mine by the engineers of the Mexican company. They started with four winches, not over 20 h.p. apiece, and fooled along for nine years, finally getting the water out; then, in 1881, they purchased a good Fraser & Chalmers' double-drum double-cylinder winding engine of 120 h.p. Mr. Dwight Furness, who was in our party, told me that when he visited the mine in 1888, the yard was full of women engaged in sorting ore. They sent 300 tons of this ore to the mills, the remainder being shipped to Germany. These operations stopped in 1892, and the water has been rising in the shaft ever since. I saw some of the little hoists used in 1872; they had tooth-gearing made of mortised wood; they came from Manchester, and were

Two Views of the Tiro General. Old Head-Frame, Boiler House, and Chimneys

The Tiro General or Valenciana Shaft

brought on ox-carts from Vera Cruz, a distance of fully 500 miles.

A little farther north is the other great shaft, that of Guadalupe, which is 22 feet in diameter, and 325 metres, or 1,072 feet deep. It has a hexagonal collar built of masonry; through it a great deal of material was hoisted, the dump being the largest on the Veta Madre, containing 350,000 tons.

The unwatering of the Valenciana shaft must have been a wonderful spectacle; the story of it is told in the old company's records. When they began, there were four steam-hoists raising as many iron buckets restrained by wire guides. The water being high in the shaft, it was not possible to anchor the guides to the bottom, so they were attached to a big wooden float, which was weighted until it sank. Then the upper ends of the guide-ropes were run over sheaves, in order that they might be paid out as the water was lowered. As long as only one hoist was running, all went finely; but when all four got to work, the apparatus, that is, the float, guide-ropes, and *toneles* (bailing-buckets), commenced to twist until the whole lot of them were completely wound up in an utterly hopeless tangle. The bailing operations had removed the water unequally over the area of the shaft, and this had created a vortex that caused the float to move round, twisting the 16 ropes used as guides and the eight more employed in balance-hoisting, until with rapidly increasing gyrations, the

float became the base of a tangle that baffled description and made the engineers hysterical.

After the unwatering was completed, in 1881, Miguel Rul made a speech[25] before the Guanajuato Society of Engineers, and in that speech he dwelt upon their early troubles. The speech is on record. He describes the cylindrical iron bailers, made of galvanized sheets of No. 22 iron, with wooden bottoms and rawhide valves; he tells of the various difficulties with the valve mechanism and over-winding, and then he finally comes to the trouble connected with the attachment for the eight wire-guides below the surface of the water in the shaft. I quote his words: "On making the general trial with the four hoisters, after many partial trials which had resulted well, we noticed a phenomenon which disconcerted us. The effect of the different movements on the single timber-frame, to which the guides were attached below water-level, commenced to stir the water and to produce a tumultuous motion of rotation, which finished by resembling a water-spout and winding up the cables and guides, completely interrupting the manœuvres. Many times we four engineers repeated the trial through a whole day, and the following day with only three (since he who recites this fell ill), without obtaining any favorable result. The three companions came to the bedside of the patient completely disheartened and sad, as was to be expected,

[25] This speech, before the Guanajuato Society of Engineers, was published in their *Bulletin*, and is dated August 5, 1888.

but at the same instant the same exclamation burst from the mouths of all, the very syllables falling together, without anyone of the four being able to say, 'I was the first to speak'; we shouted, *'We will secure the fixity of the frame with diagonal props resting against the walls of the shaft'!* This common idea was the equivalent of the *Eureka!* of the Greeks. It raised the patient from his bed, re-established happiness and, when put in operation, it gave the much desired result. The ninth day of June, 1873, the unwatering was inaugurated with great solemnity."

What a scene it must have been; the courtyard fairly buzzing with the noise of the little hoists, the shouts of the bewildered engineers, the imprecations of the workmen, and the tremendous turmoil of the water in the big shaft as the guide-ropes twisted into a hopeless coil! And then the silence when the whole came to a futile conclusion, the operations remaining suspended until those three mine captains, gathered around the bed of their invalided comrade, were suddenly inspired with the happy solution of their trouble. The courtyard is empty now, the waters have again invaded the shaft, and the vertical rays of sunlight once more pierce the gloom within the stagnant pit.

Chapter 26

THE MALACATE AND ITS OPERATION—THE AVIO SYSTEM—ELECTRIC POWER—A CURIOUS DIFFICULTY—HOW THE EAGLES INTERRUPT THE CURRENT—A STRIKE.

S a rule the miner does not choose the top of a hill for the site of his shaft; he goes where he can economize on his sinking, without depriving himself of the chance to distribute the waste rock. At Guanajuato the shafts are on knolls, some of which rise to the dignity of hills. The reason for this was the space the Spanish miners wanted for their *malacates* or horse-whims. At each shaft there were so many of these that a yard of 100-foot radius was required. When this had been planned they would begin to construct a wall just beyond the end of the arms of the *malacate*, the wall being built with the waste (extracted from the shaft), which was then filled into the enclosure until the yard had a level surface. The *haciendas* were rarely near the mine, they were erected in the town, for the sake of safety and convenience. The ore was carried on mules to the *patio* establishments, which were custom mills.

A Malacate or Horse-Whim

On the Road to the Mines

The mines were not worked by their owners but by parties who secured a lease in perpetuity, termed an *avio*, which gave them (the *aviadores*) the right to do what they pleased in the mine, and to make contracts for the disposal of the ore. The *aviadores* charged, as a lien against the mine, all expense of whatever nature they incurred, such as development, operation, taxes, plant—in fact, everything. Against these items they credited the net returns obtained from the sale of ore, but being able to dispose of it wherever they pleased, they built *haciendas* on their own account and then made numerous contracts for the treatment of the ore, and mixed the several grades of it so that the yield could not meet the treatment charges. Then, as the owner never got a centavo unless there was a balance to credit, he never received anything. The mine ran up an ever-increasing debt until it amounted to an impossible sum; thus, for example, in the group of mines held by the Guanajuato Reduction & Mines Company, the indebtedness amounted to 6,000,000 pesos, most of this sum being entered against four properties, namely, the Rayas, Mellado, Cata, and Valenciana.

The American company bought the *avio* contracts and the debt becomes payable to these new owners; the company inherits all the old contracts, including the agreement for ore-treatment; it will never have to pay the former—almost nebulous—owners unless the profits to the mine from sale of ore to reduction works first repay the accumulated interest and then grow

into a surplus. All the contracts are based on the old treatment charge, which was: 360 grams silver per ton to be deducted from contents of ore, the balance to be paid for at the rate of 3 centavos per gram; and the gold contents up to 6 grams per ton to be paid for at the rate of 30 centavos per gram; between 6 and 15 grams, the payment to be 45 centavos. As the average ore of the best mines contains 350 to 400 grams silver and 3 grams gold, it is pretty obvious that the *aviadores* will not have to make an accounting. Several attempts, naturally, have been made to break these curious Spanish contracts, but in vain. The *aviadores* are the unquestioned owners of the mines today and no court can invalidate their peculiar rights.

The new enterprises at Guanajuato have swallowed the *avios*, and all the big mines have passed out of the hands of the native population. It is a fact that the Mexicans look upon the American operations with scepticism, largely because earlier efforts made by foreigners came to grief. They are inclined to regard with humor the removal of dumps and the working of abandoned mines; in consequence, although the old work was done by their own people, only a few local merchants have any financial interest in the present profitable undertakings.

The introduction of electric power has been of great help in the re-opening of the old mines at Guanajuato. It used to cost 400 pesos per horsepower per annum, burning oak for fuel and using compound engines. Now the rate is five pesos per

A Bit of Old Mexico

A Distant View of Guanajuato

The Villas of the Presa

horse-power month for the right to use electricity, and 0.026 centavos per kilowatt-hour, the latter being equal to about five pesos more per month if running steadily, making the cost 10 pesos per h. p. month. The power comes from the falls of Zamora, on the Duero river, in the State of Michoacan and 101 miles from Guanajuato. There 45,000 to 60,000 volts are generated, with a step-down to 15,000 volts and again to 440 volts. Thus 4,000 h.p. is generated, and another plant of equal capacity is about to be erected. Time flies. This must now be completed, for I speak of more than a year ago (November, 1905), when I visited Guanajuato.

The natives were troublesome at first; they cut and stole several hundred metres of copper wire. Two men were killed by a live wire, after public warning of the danger. There was also some difficulty at first in transmitting power, by reason of the sudden change in temperature at dawn, when there is a rise of 15° C. This causes condensation of moisture on the porcelain insulators, which remain cool after the temperature of the surrounding air has risen. The moisture on the insulators is sufficient to cause the current to short-circuit between the iron pin of the insulator and the cross-arm of the iron tower. This happens between 5 and 6 A. M. The only way to stop it is to turn off the current, so that there is a break for an hour. However, energetic investigation into the subject will solve this difficulty, a return to wooden pins being possible. At first the break in

transmission was attributed to the malice of discharged employees and then to the eagles, many of which were found dead at the base of the towers. They alight on the top of the iron supports at dawn and stretch their wings so as to arc across the wires, being killed instantly, but establishing a short-circuit through themselves before they drop.

Chapter 27

THE PEREGRINA MINE—OLD SPANISH WORKINGS—SHRINES UNDERGROUND—ACETYLENE LAMPS—SAMPLING A DUMP.

IN the Peregrina mine, near Guanajuato, I had a good opportunity of examining some typical old Spanish-Mexican workings. We entered by a door into a small gallery and thence through the opening or mouth of the mine (*boca de mina*) that descended into the darkness. The way was down a twisting stairway that zig-zagged within the vein-walls; the steps were laid in lime mortar, the general slope varying between 45 and 56°. Such passages are common in the old Mexican mines; they are made in stopes, the filling of which has been used to build the masonry of the stairway. At intervals, shrines are to be seen; there was one 30 feet from the entrance, just at the end of daylight, and there was a principal shrine in a parapet above the big workings (*obra grande*) at the 100-ft. level. Every shrine is guarded by lighted candles, left there by the miners; and it is said that they will even go up and down the underground passages in the dark in order to save candles for this purpose. At about 5 o'clock, when

the shifts change, there are 150 to 200 candles burning before the principal shrine, forming a grand illumination, the effect of which is heightened by the cavernous old stopes that yawn in front of the sacred image. As they pass it, the men stop and make a genuflection, with the sign of the cross. Descending farther, the stairway becomes wider as it passes into the big stope and we noticed another shrine—a cross set in a frame, with a solitary candle; this marks the spot where a man carrying drills (*refacctionero*) tripped at the head of a series of steps and fell fatally.

The big stope is a cavernous excavation 250 feet long, by 450 feet deep, and 8 to 25 feet wide. The footway at the end of the first stairs, about 100 feet from daylight, is blasted in the wall of the lode and is provided with a parapet of masonry. Leaning over it, one looks into an abyss, the effect being like a miniature Cornice road underground. The lode is nearly vertical, changing from 80° W, at the south end of the mine, to a dip of 70° E, at the north end. The ore is from 8 to 20 feet wide; it consists of quartz, partly ribboned and traversing a breccia, the edges of which show replacement; it follows a line of fracture in the breccia; where the vein is tight and the quartz massive, the silver is highest in proportion to gold, ranging from 50 to 55%. Going south the lode becomes more open, the vugs contain clay, and there is such evidence of leaching as is usually seen close to the surface. In this part of the mine the proportion of silver to gold is smaller. The Mexicans could not

THE BASKET STORE

BY THE WAY

Shrine in the Peregrina Mine

Hacienda San Francisco de Pastita

work the gold ore because the *haciendas* paid nothing for gold and the ore-buyers gave only 30 centavos per gram, when it is really worth 66 cents or 132 centavos per gram. This ore cannot be sorted like that which is rich in silver, the argentite being visible in threads and spots, while the metallic gold is disseminated in particles too small to be seen. The argentite sometimes impregnates the chalcedonic quartz so delicately as to make a moss agate.

Our progress through the mine was lighted by two *peones* carrying *mechas* or torches. Mr. E. P. Ryan, the superintendent of the property, carried an acetylene lamp, so that the old and the new were well contrasted. The time may come when acetylene will be in general use underground, but it will not become popular until the present lamp is superseded by something better. As it is now, you have a small can that holds the granulated calcium carbide and to this water is added; then the cover is securely replaced, and the chemical action produces the acetylene gas, which is lit as it escapes through a small aperture. The smell of it gave me a headache, both in Mexico and in the Lake Superior copper mines, the two districts where I used acetylene lamps. But there is a newer invention that promises to prevent the escape of gas and the consequent headache. The emission of gas is nicely regulated and all of it is burnt in the process of illumination.

We met boys (*tanateros*) carrying waste in *tanates*, the bags made of the fibre taken from the *ixtle* plant,

a variety of *maguey*. We were passed by other natives descending to the place of their work, whistling as they went at a trot down the rough steps.[26] Then, in contrast to such breathing antiquities, we found a couple of young mining engineers[27] who were taking samples in a thoroughly modern way, aided by Mexican miners to do the moiling. The quartz ore was hard and 10 to 15 feet wide, so that two moils were blunted for each foot of sampling. They used the straw hats of the *barreteros* to catch the sample. As we proceeded, I could see by the white channeling across the dark drifts that the work was being well done.

Speaking of sampling, reminds me of the old dumps and the way they were tested. At the Peregrina, this work was done by Mr. George A. Schroter. He did it with system and care. An aggregate of 250 feet of shaft-sinking was required; one shaft was as much as 70 feet deep, the usual depth being 40 feet. Each shaft was 3 by 4 feet in the clear; it was kept open by small timbers, 4 by 6 inches in cross-section. Two-inch round oak spiling was driven over a 'bridge' by double-hand hammers, as fast as the ground yielded, in consequence of the removal of the material at the bottom. The hoisting was done in baskets. The average cost was $1.25 for the first metre and then 25 cents extra for each succeeding metre of

[26] A Cornishman thinks it unlucky to whistle when underground.

[27] G. A. Kennedy, of the Colorado School of Mines, and L. C. Pearce, of the Michigan College of Mines.

A Big Stope in the Peregrina Mine

Sorting Ore at the Peregrina Mine

sinking. The material obtained from each metre of shaft was kept separate and sorted, for 25 centavos per ton. This sorting was done by women, who made three piles, consisting respectively of fine ore, lump quartz, and waste. On the day of my visit there were 60 to 70 women at work, handling 100 to 110 tons per day. They are better than men—more steady—because they do not stop to smoke a cigarette; nor do they steal as much as their husbands and brothers. The sorting is done with a 3-lb. hammer, a horn spoon, and a wicker basket (*chiquihuite*) reenforced with hide, holding about 30 pounds of ore. The dump contained $8 to $9 per ton, 70% of this assay-value being in gold. In the open-cut, where the ore is mixed with wall-rock, the assays averaged about $4.50 per ton. Underground, it was found that the filling of old stopes ranged between $5 and $10, being highest in the southern part of the mine, where the ore is more difficult to sort.

The buying used to be done entirely at sight, the grade and weight were both guessed, with plentiful allowance for error and deception. The *buscon* or tributer would make a pile and put big chunks of good ore on the outside, and then fill his mouth with water and squirt it over the pile, so as to make a fine showing of black (silver) streaks across the gray rock, on the same principle as the old woman polished the apples for sale on her stall.

Chapter 28

THE DUMPS OF GUANAJUATO—HOW TO SAMPLE—THE MEXICAN IDEA—TWO TRUE STORIES—THE BITER BIT.

HE dumps of Guanajuato have figured largely in recent prospectuses, many companies having been organized with the particular purpose of treating the ore left by the old Mexican managements. On careful inquiry, I can give the average assay-value of the best of these immense accumulations as 4 to 6 ounces of silver, and 1.5 grains of gold per ton, equivalent to, say, $4 per ton.

When the American invasion began, the Mexican was not slow to appreciate his opportunity. In one case, *peones* were set to work removing the dump in sacks and loading *burros* with it, so as to impress a visitor with the idea that the stuff was fairly rich. But grab samples gave only five ounces of silver per ton. It was hardly worth sacking!

As regards sampling, in all the discussions on this subject while I was at Guanajuato, emphasis was laid upon the danger of doing the work without trustworthy assistance. When using outside help, it is

difficult to prevent salting, if well planned, unless the following three operations be performed:

1. Take samples with the help of the miners available.

2. Blast the lode at a few points and take check samples.

3. Cut down another set of samples yourself, with the aid of the one personal assistant, without whom such work should not be undertaken.

Mexican miners make poor assistants to an engineer sampling a mine. When the groove is being cut across the vein, they linger in the rich ore from force of habit; it is hard to make them understand that the poor quartz must be included. To this very day, the Mexicans at Guanajuato deride the American method of sampling. One of our friends had taken a large sample laboriously and carefully; he was just in time to see the foreman of the mine in the act of throwing out pieces of poor rock. "*Tiene nada*," "It carries nothing," he explained, as though it were foolish to include anything but rich ore. Other engineers can tell you of similar experiences, when, after breaking a sample with particular care to make it a true section of the vein, their Mexican helper has picked out the barren-looking quartz. The whole training of the native for generations has been to sort his ore, rejecting the poor stuff, and he cannot get it into his head that anyone should do otherwise. But he is not the only eccentric; when I was in Western Australia, during 1897, the owners of mining

claims, or their representatives, did not hesitate to express surprise at my omission to sample the small patches of specimen ore. One incident I shall not forget, for I have a memento of it. Having been retained to inspect a mine at Red Hill, near Coolgardie, I was escorted to the spot—50 miles away—by a Mr. Patrick Walsh, a local celebrity of the boom days. His language was picturesque and free, he had rudimentary ideas of mining, and he took me for a 'tenderfoot' —they call them 'new chums' in Australia. The mine had several shafts and a couple of shallow adits, most of which had but little ore to show, but on the top of a small ridge there was a trench that exposed a quartz cropping in which glistened a patch of beautiful specimen ore—ounces of gold to the pound of quartz. I admired it and proceeded to pass on, but he asked me if I did not intend to take a sample, for in those days pseudo-experts took a dozen samples of poor quartz, and then a thirteenth unlucky one of specimen stuff, and averaged the lot, with the result that 4 dwt. ore appeared in their report as running 2 oz. 10 dwt., or something like it. Seeing that Mr. Walsh would think I was not fair to his mine if I demurred, the sample was taken. But it was never assayed; the gold was melted, and I now possess a pair of handsome cuff-buttons to remind me of Red Hill, Western Australia.

To return to Guanajuato; sampling of the streaky lodes in that district is difficult; re-sampling of the same groove is known to have given three such

divergent results as 1,800, 350, and 150 grams of silver per ton. The discrepancy is due in part to the fact that the threads of argentite are thin and wavy in direction, so that when the groove is made deeper by a later cut, the amount of silver mineral obtained is less or more, according to the chances of striking or missing a streak or *hilo* of argentite. Re-sampling is usually accompanied, in the case of an intelligent engineer, by the special desire to avoid taking too much of the rich stuff, and this is apt to cause a leaning the contrary way. On the other hand, the first sampling —made for the vendor—is likely to be left to the Mexicans, who instinctively put too much of the soft argentite into the hat that holds the ore as it is broken.

The story is told of a mine that, along its main level, showed a width of 8 to 10 feet of beautiful quartz ribboned with black threads of rich mineral. The back of the drift looked handsome. An option was secured by Americans residing at Guanajuato, who knew rich ore when they saw it. The sampling done by an engineer in behalf of a putative purchaser gave the astonishingly low result of an average of $2 per ton. A protest against this finding ended in the breaking of a few tons of ore with a view to checking the sampling, and the result was 5 cents per ton less. The black streaks were not argentite, but stibnite!

There was another story of an ore-purchasing agent who found that the smelter returns at Monterrey were 30% less than his own sampling, on which he had made settlements with the Mexicans. He dis-

covered that the ore, when being sampled at the mine, was turned over in the teeth of a wind, which blew the fine black (silver) dust over the fraction representing the pulp that went to the assayer. This residual portion was always placed to leeward. He lost 8,000 pesos, but took his medicine like a sportsman. In the course of time, it was decided to sample at the receiving station instead of at the mine; there was a nice yard (*patio*) available for the purpose, it was paved with red brick of the usual soft character. The *buscones* (tributers, or lessees of the mine) sent a representative to watch the sampling in their interest, and he noticed that the sweeping of the floor threw red brick-dust into the sample. He became fussy, and insisted that the objectionable material should be ejected, and it was. The ore-buyers' agent did not prove obdurate, for the brick-dust included fine particles of rich ore that filtered to the bottom, making a mixture 15% richer than the average. The 8,000 pesos that had been lost were soon recovered, and a few more to make them comfortable.

Chapter 29

THE GEOLOGY OF THE VETA MADRE—A BIG FAULT —POSITION OF THE OREBODIES—A CROSS-SECTION —HUMBOLDT'S DESCRIPTION—WHAT IS A TRUE VEIN?

SOME idea of the general geology of the Guanajuato district is obtainable along the road that crosses La Bufa. I went this way to the Peregrina mine, seven miles from the city of Guanajuato, and incidentally formed my first notions concerning the country enclosing the Veta Madre.

The accompanying cross-section (Fig. 18) I owe to Señor Ponciano Aguilar, of the Mexican Geological Survey. It illustrates the fact that the Veta Madre follows a fault of big throw, so that the foot-wall is shale[28] and the hanging a series of layers of volcanic fragmentary material. The magnitude of the fault that made the Veta Madre is clearly indicated.

In the shale of Guanajuato were detected the first Triassic marine fossils found in Mexico. They were bivalves, not well defined. The shale is meta-

[28] The Mexican geologists use the term 'schist' for this rock, but it is a misnomer.

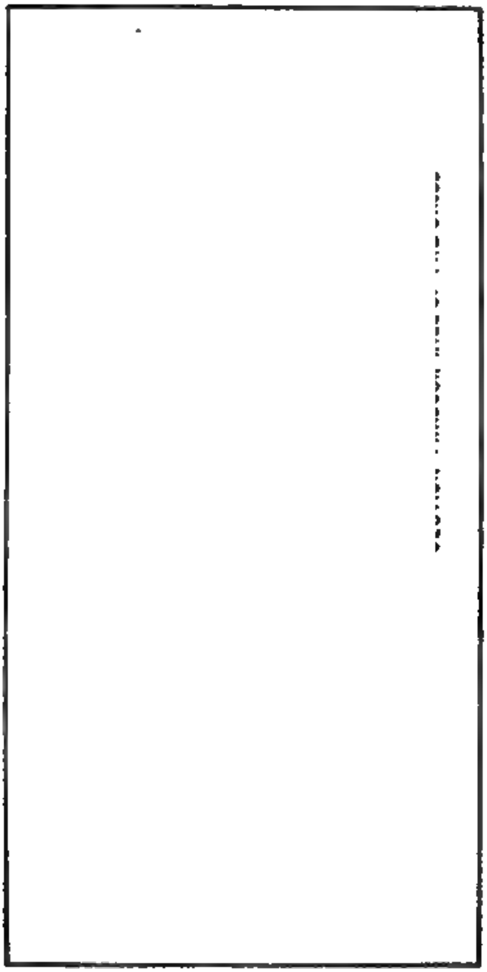


Fig. 18. Cross-Section of the Veta Madre. After Ponciano Aguilar.

GUANAJUATO
La Bufa in the Background

A Typical Street in Guanajuato

morphic and resembles the Upper Trias of Zacatecas, where fossil remnants of the same kind are found.

The Miocene agglomerate of the hanging wall, usually called the 'red conglomerate,' or Guanajuato formation, is overlaid by breccia and rhyolite tuff, termed 'sandstone' by the *ouitlanders*, while the Mexican geologists call it *lozas*[29]. Next comes more agglomerate and then tuff, the latter a succession of layers of volcanic fragmentary material, altogether

Fig. 19.

1,200 feet thick, and reminding me of the formation that prevails in the San Juan region of Colorado. On

[29] *Lozas* literally means flagstones, it is a term applied to the water-laid volcanic dust, porous in texture and well stratified, which looks like a sandstone. It lies on the top of the 'red conglomerate' and below the other tuffs. The *lozas* constitute a thinly bedded formation of green rocks, only from 10 to 40 ft. thick. At some places the texture is fine enough to make them equivalent to a 'free-stone,' eminently suitable for building purposes. The façade of the Juarez theatre is built of this material, and the ornamental stone-work all over Guanajuato is derived from this source.

the farther edges of the eruptive centre these clastic rocks are replaced by lava flows of dense rhyolite. The foot-wall of the big lode, as seen in this section, is Miocene agglomerate, and different from the foot-wall rocks north of the Sirena mine; the change of formation being due to a cross-fault coming into the Veta Madre on its foot-wall side, producing a down-throw of the southern portion of the foot-wall rocks. This is illustrated in the accompanying drawing (Fig. 19), made from a sketch given to me by Mr. R. H. Burrows, an experienced economic geologist, resident at Guanajuato. The Sirena mine is indicated at *A*; at *B*, the approximate relative position of the Valenciana mine, the throw is at least 6,000 feet, while at *C*, the place of the Cedro mine, the throw is probably 2,000 feet. The difference in throw is not effected by bending of either side of the Veta Madre, but by step-faults.

Northwest of this cross-fault it is difficult to determine the extent of the displacement along the Veta Madre, because the relation of the agglomerate to the shale has not been established. After the lode passes southeast of the cross-fault, the throw can be determined by estimating the distance from the top of the red agglomerate on the hanging-wall side to the top of the same formation on the foot-wall side. This distance is shown in the section *B B*, in Fig. 20, where it is represented as 2,000 feet. Referring to the section *C C*, there is no formation now in contact above or below the shale, and the bottom of the red

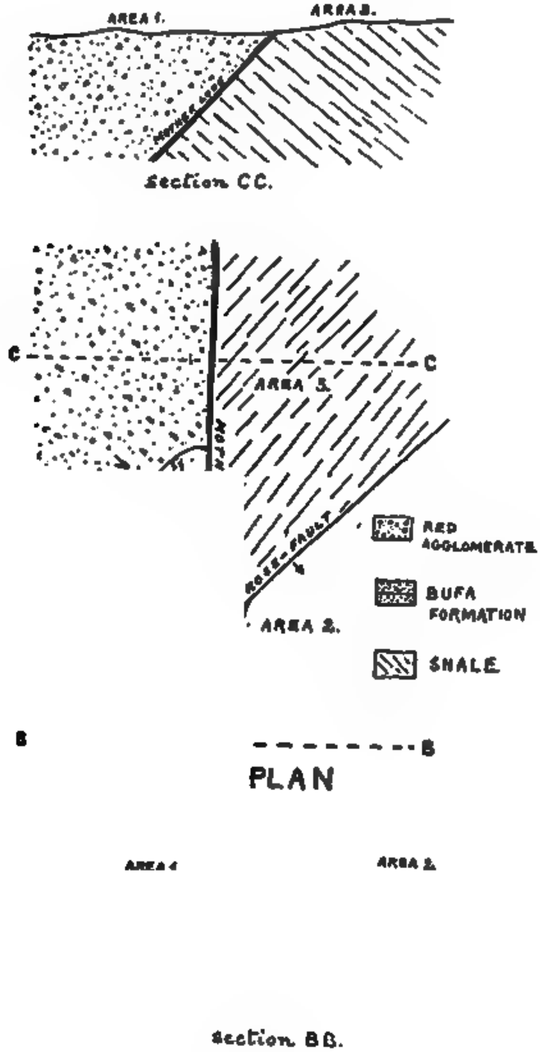


FIG. 20. PLAN AND SECTIONS OF THE VETA MADRE.
After R. H. Burrows.

agglomerate is nowhere visible. As the shale is older than the red agglomerate, the throw will be represented by the known thickness of the red beds, plus the amount of the latter that has been eroded on the foot-wall side of the lode. Of these two factors, which together make up the sum of the throw, only the first mentioned is definitely known. Starting downward from the top of the red agglomerate on Sirena Mtn. this formation is traced all the way to Marfil, a distance of six miles, exhibiting a constant strike and a dip varying from 5 to 30° east. The thickness thus represented is fully 6,000 feet, so that, omitting the other factor, it is well within the mark to estimate the throw at 6,000 feet.

At the Sirena mine, the foot-wall is shale (probably Cretaceous), varying from argillaceous to calcareous, from clay to lime. On the hanging the layers of agglomerate dip eastward toward the lode. The agglomerate becomes deeper as one goes southeast along the outcrop of the Veta Madre; it feathers out to nothing at the Valenciana, and at Bustos it is about 200 feet below the bottom of the valley. The slope taken at right angles to the strike of the Veta Madre, is about 30° downward and toward the vein, the strata therefore making an angle of approximately 75° with the dip of the Mother Vein. The dip of all the bedded rocks in the district is about due east-west, and the strike of the lode is northwest-southeast. It is not a simple vein, but a vein-system within a zone 50 to 600 ft. wide. The principal ore-

bodies in the Sirena mine occur near the intersection of the Amparo vein coming in from the hanging wall. Much the same is true of the orebody in the Rayas mine, formed at the intersection with the Santa Toribio vein, which also comes into the main lode from the hanging-wall side, the ore pitching with the line of this intersection.

At the time of my visit, the Sirena was in bonanza; a new orebody had been found on the fourth level in a raise, where it touched the quartz of the old foot-wall stopes. At the fifth level—800 feet (on the dip of the vein) below the Purisima adit and 1,320 feet from the outcrop—cross-cuts and raises had proved that there was 120 feet of pay-ore, which, allowing for the diagonal course of the cross-cut and the dip of the lode, was equivalent to a width of 65 feet. Another cross-cut, 300 feet farther east, had proved a width of 45 feet. One section showed three ore-streaks, parallel in strike, but converging in dip toward the foot-wall.

In Fig. 21 I have drawn a generalized cross-section of the Veta Madre as it appeared to me on the fifth level of the Sirena mine. *A A* is the hanging wall and *C C* is the foot-wall; *B B* is the lower limit of the main vein and is called the *intermedio*, or intermediate wall. The distance between *A* and *B* is 25 to 75 feet, between *B* and *C*, 75 to 150 feet. On the foot-wall there is a vein, from 1 to 6 feet wide, of quartz, which is not ore. The shale is bent near the foot-wall and is shattered between that line and the *intermedio*. *B B*

represents the line of the fault along which a width of shattered rock has created an ore-channel. Between *B* and *A* there are numerous stringers of quartz,

FIG. 21.

some of which is ore, but the main orebody extends from the hanging into the agglomerate. The so-called 'foot-wall quartz' has been stoped on the fourth level for a width of 20 feet, and on the higher levels

this body of poor quartz is 200 feet wide and there it lies against the shale. The lode is broken by step-faults east of the Principe shaft, the fault-planes pitching east at a strong angle. For a distance of 1,200 feet on the vein, northwestward from the Principe shaft, the lode is ore-bearing, to a varying extent, and in bodies of different shape. The pay-ore lies in soft brecciated ground, exhibiting traces of oxidation and lying between the hard vein-quartz of the foot-wall and mineralized ground, the limit of which has not been determined. It is an impregnation of irregular shape, extending along the structural lines of the agglomerate. At the time of my visit the ore as sent to the mill yielded 517 grams of silver and 2.76 gm. gold per ton. The agglomerate does not wholly lose its identity by reason of impregnation with ore, and it is necessary to sample carefully in order to determine where profitable exploitation will cease. It is fair to say that the cyanide process has done more to widen pay-ore than the geologist, that is to say, the decrease in the cost of milling has enabled the manager to treat profitably material previously considered too poor. Where the lode is not rich the distinction between quartzified country and profitable ore is determined by the assayer, and not by the mineralogist.

The stalactites of iron on timbers and on the foot-wall of the old workings carry silver. As much as 30 grams, say, an ounce of silver, has been detected in such deposits formed within one year. The general assay-value is 5 to 20 grams per ton. After rains the

water of the mine contains 2½ to 3% sulphuric acid and it will eat through an iron pipe ⅜-inch thick within 60 days.

I was informed that the orebody of the hanging wall, in the Sirena mine, was found while blasting for a cross-cut, intended to make room for a new hoist underground. The appearance of this ore suggests that it was formed by one of those movements that took place subsequent to the formation of the main fracture of the Veta Madre and its accompanying vein-matter; this later movement evidently shattered the older quartz-filling and then passed through the hanging-wall country so as to make a big mass of brecciated ground, suitable for infiltration by mineral solutions, which re-cemented it with calcite and the more valuable metallic minerals. Diamond-drilling ought to be useful in exploring this ground; for the orebodies are large, but not connected. The old stairways and communicating passages appear often to be the bottom of underhand stopes, and therefore suggest the lower limit of profitable ore at the time the work was done.

The accompanying photograph illustrates a part of the Veta Madre as seen in the Rayas mine. It is near the foot-wall, as indicated by the fragments of shale, which are partly silicified at the edges. Black threads of argentite traverse the white quartz.

The geology of the Veta Madre has not received detailed study as yet, at least nothing has been published commensurate with the size of the subject, so

A Bit of the Veta Madre

A MEXICAN OX WAGON

that Humboldt's observations still possess a commanding interest. I shall quote from the old English translation already mentioned. He says: "The famous vein of Guanaxuato, which has alone, since the end of the sixteenth century, produced a mass of silver equal to fourteen hundred millions of francs,[80] crosses the southern slope of the Sierra de Santa Rosa." Beginning to touch upon geological matters, he states that "the most ancient rock known in the district is the clay slate (*thonschiefer*) which reposes on the granite rock of Zacatecas. It is of an ash-gray color and is frequently intersected by an infinity of small quartz veins. I consider this clay slate as a primitive formation, although the beds with very thin folia and which are surcharged with carbon, appear to approximate a transition clay slate. These beds (*hoja de libro*) are for the most part near the surface. On digging the great pit (*tiro general*) of Valenciana, they discovered banks of syenite or hornblende schist and true serpentine, alternating with one another and forming subordinate beds in the clay slate."

Humboldt wrote in French, so that his use of the term *thonschiefer* indicates that he was thinking of the Erzgebirge, at that time—just one hundred years ago—the most scientific mining centre in Europe. His description of the shale, which constitutes the foot-wall of the Veta Madre, is correct. It does exhibit a ramification of quartz veins. But the label

[80] £57,754,620 or, say, $285,500,000.

'primitive' will not do, for the formation is probably Cretaceous; moreover, 'primitive' is a word belonging to an outworn idea, that the basement rocks were the original cooled crust of the earth. Petrography knows no simple starting point; the rocks we see are only in a particular stage out of the many through which they pass in the course of their geological evolution. The modern geologist begins with the old crystallines, earlier than fossils. The undermost rock now known is a granitic batholith, which seems in places to have invaded the oldest schists. This granite may be an original igneous rock for aught we know, it is probably not a fused sediment, and is the nearest approach to anything 'primitive.' The crystalline granite, formed by slow cooling from a molten magma, when exposed to weathering at the surface of the earth, becomes disintegrated into sand and clay, which, being deposited in the ocean depths, are recemented and again solidified in process of time, passing through chemical and physical changes that make sandstone out of the sand, and shale out of the clay, at first, and then by further interplay of subterranean pressure, heat, and chemical action, these become on the one hand quartzite, on the other slate, with a mixed product of schist between them.

The Valenciana shaft passes through the carbonaceous shale, with layers like the leaves of a book (*hoja de libro*) and penetrates the intrusive diorite, the decomposition of which, in places, gives the magnesian rock that Humboldt called 'serpentine.' He con-

tinues: "Porphyry forms gigantic stony masses which appear at a distance under the strangest aspect, frequently like ruins of walls and bastions. In the country they go by the name of *buffa*. This porphyry, of which the Sierra de Santa Rosa is chiefly composed, is generally of a greenish color." Colors in rocks have ceased to have the importance they once had, for we have learned that the same rock can change its appearance while retaining an identity of composition. The name *bufa* still lingers at Guanajuato (but it is spelled with one f), and has almost replaced the higher sounding 'Sierra de Santa Rosa.' The sculptured summits and bold cliffs of La Bufa are due to unequal weathering of the rhyolite tuff that caps the Guanajuato series. Even in those days the term 'porphyry' played many parts.

Continuing, Von Humboldt mentions that "on the southern slope of the Sierra, the clay slate is covered with free-stone of very old formation. This free-stone (*urfels-conglomerat*) is a breccia of clayey cement, mixed with oxide of iron, in which are imbedded angulous fragments of quartz, lydian stone, syenite porphyry, and splintery hornstone." He speaks of the dip being opposed to that of the clay slate. Above this 'free-stone' there is "an agglomeration (*lozero*) of later date from which the finest hewn stone is manufactured."

The free-stone is a fine-grained tuff, used in the building of the city of Guanajuato, as already mentioned; it is soft enough to be easily worked, and yet

hardens on weathering, so as to be durable. It is the *cantera* of the Mexicans. This formation occurs both above the shale of the foot-wall country, as Humboldt states, and also on the hanging-wall side; in fact, it marks the extent of the great fault of 1,200 feet, along which the Veta Madre was made. On the hanging-wall side the dip of the country is nearly at right angles to the vein, which cuts strongly across the bedding, and, for a great distance, follows a line along which the later tuffs and breccia are opposed to the shale. But on the outer edges of the mining district, the vein cuts through the younger rocks also. Humboldt saw this; he says: "The vein traverses both the clay slate and porphyry. We have already stated that it has been wrought for a length of more than 12,000 metres; and yet the enormous mass of silver which it has supplied for the last hundred years, sufficient of itself to produce a change in the price of commodities in Europe,[21] has been extracted from that part of the vein alone contained between the pits of Esperanza and Santa Anita, an extent of less than 2,600 metres (8,529 ft.). In this part we find the mines of Valenciana, Cata, San Lorenzo, Animas, Mellado, Fraustros, Rayas, and Santa Anita, which at different periods have been very highly celebrated."

According to Humboldt, the European miners had been in doubt whether to consider the Veta Madre a "true vein" or a "metalliferous bed

[21] An effect produced seventy years later, by the equally tremendous output from the Comstock lode, in Nevada.

(*erzlager*)." He then proceeds to give some sound geological views:

"If we examine only the *veta madre* of Guanaxuato where the roof and the wall, in the mines of the Valenciana or Rayas, are of clay slate, we might be tempted to acquiesce in the latter opinion; for far from cutting or crossing the strata of the rock, the vein has exactly the same direction and the same inclination as its strata; but can a metalliferous bed which has been formed at the same period as the whole mass of the mountain in which it is found, pass from a superior to an inferior rock, from porphyry to clay slate? If the *veta madre* was really a bed, we should not find angular fragments of its roof contained in its mass, as we generally observe on points where the roof is a slate charged with *carbone*, and the wall a talc slate. In a vein, the roof and the wall are deemed anterior to the formation of the crevice, and to the minerals which have successfully filled it; but a bed has undoubtedly pre-existed to the strata of the rock which compose its roof. Hence we may discover in a bed fragments of the wall, but never pieces detached from the roof."

The attempts to define a 'true vein' have not ceased even a hundred years after the above words were written. While the debate is adjourned and resumed at intervals by savants, the miner has disregarded evasive distinctions and has proved by his profitable toil that "metalliferous beds" are just about as good as the "true veins." The Calumet & Hecla,

the Leadville orebodies, the Aspen contacts, the saddle reefs of Bendigo and Broken Hill, the lenticular masses of Rio Tinto, the disseminated copper deposits of Bingham and Ely—to mention only a few—are representative of occurrences that do not belong to what the schools of Saxony and Cornwall labeled 'true fissure veins.' Nevertheless, Humboldt's effort to distinguish betwen an ore deposit contemporaneous with the formation that encloses it, and one that has originated along later fractures crossing such rocks, is not without interest. He refers to the inclusion of rock fragments in the *Veta Madre* thus:

"Its extent varies like that of all the veins of Europe. When not ramified, it is generally from 12 to 15 metres in breadth; sometimes it is even strangled to the extent of half a metre; and it is for the most part found divided into three masses (*cuerpos*), separated either by banks of rock (*caballos*) or by parts of the gangue almost destitute of minerals. In the mine of Valenciana the Veta Madre has been found without ramification, and for a breadth of seven metres, from the surface of the ground to the depth of 170 metres. At this point it divides into three branches, and its extent, reckoning from the walls to the roof of the entire mass, is 50 and sometimes even 60 metres. Of these three branches of the vein there is in general but one alone which is rich; and sometimes when all the three join and drag one another, as at Valenciana, near the pit of San Antonio, at a depth of 300 metres, the vein contains

immense riches of an extent (*puissance*) of more than 25 metres. * * * Valenciana is almost the sole example of a mine, which for forty years has never yielded less to its proprietors than from two to three million of francs (£82,506 to £123,759) of annual profit."

Here we have the Spanish equivalent of our term 'horse' literally translated into *caballo;* it is the included rock that the vein rides, passing astride of it. If the branches of the vein do not re-unite, the result is a split or embranchment; if they come together, it is a 'horse.'

Mexican mining terms are frequently distinguished by their aptitude. The hanging wall is called *alto* (high or up), the foot-wall is *bajo* (down or low). But at El Oro I found that the natives spoke of the hanging as *reliz* (pronounced like release). It is a word signifying a landslide or slip, and as suggesting a plane of parting or what a miner calls a 'shooting course,' it struck me as excellent. The hanging is also described as *reliz arriba*, or *arriba* by itself. Waste is *tepetate.* All stringers are called *hilos, hilo* being a thread. Ore that is speckled with black sulphide is known as *mosceado*, or fly-specked, *mosca* being a fly. At Guanajuato the honeycombed quartz on the foot-wall of the *Veta Madre* is termed *cherasco.*

Dikes of andesite penetrate the agglomerate and the shale in various directions, and, as Mr. Robert T. Hill suggests, it is to them that we may impute the

latest mineralization of the district; at least, it is probable that their intrusion along lines of fracture was coincident with a period of thermal activity. The Veta Madre, being essentially a big width of rock sheeted by fractures near the contact of two unlike formations, afforded unusually favorable conditions for the penetration of ore-forming solutions, which followed the main fractures and spread outward and upward into the shattered agglomerate, where they found the inducement to precipitate the wealth of silver that is now suggested by the name of Guanajuato.

THE TANATEROS

ON THE STREET

Mexican Miners at Work. Two Drilling, Others Emerging from Underground

Chapter 30

THE DEVELOPMENT OF METALLURGICAL PRACTICE AT THE SIRENA MILL—FROM AMALGAMATION TO CYANIDATION—RE-GRINDING.

IT is worth while to tell the story of the metallurgical development at the Sirena mill, more properly named *La Hacienda San Francisco de Pastita.* The successor to the old *patio* was a mill erected in 1899; it contained 20 stamps, each weighing 1,250 pounds. The ore was first broken by a 9 by 15-in. Blake crusher and was then reduced to 20 mesh by the stamps, from which it was passed to six Boss rapid-grinding pans. Here it was re-ground, so that all save 5 to 10% passed an 80-mesh screen; and then it descended to 12 more pans and six settlers. From these the pulp went to five Wilfley tables. The capacity of the mill was 1,500 to 1,800 tons per month. The product was amalgam and concentrate.

The pans extracted 65% of the assay-value and the concentrate contained 12% more. This was on the oxidized ore. Although the concentrate contained two kilograms or 64.2 ounces of silver, it barely paid to send it to market under the smelter conditions then existing in that part of Mexico.

However, another factor came into play; as the lower workings were opened up, the percentage of recovery by amalgamation fell off until it was only 60%. Concurrently, the consumption of mercury and copper sulphate in the pans increased, while the concentrate became richer—5 to 7 kg. silver per ton. The method was changed; concentration was made to precede pan amalgamation.

By this new arrangement, the cost of milling was reduced from 7.86 pesos to 4.81. The concentration was carried further, so that the product contained 10 to 11 kg. silver and 115 gm. gold per ton; yet the weight of concentrate remained at 2 per cent of the crude ore. The higher recovery by concentration balanced the lower yield by amalgamation, the commercial result being less satisfactory because the precious metals in the form of amalgam were worth more than when enclosed within a concentrate that had to be transported to a distant smelter. Moreover, the variation in smelter rates introduced a factor of uncertainty.

Extraction finally fell below 60%. This suggested an enlargement of the mill, so as to lower the fixed charges. At this period the Government tax and the expenses in connection with realization of bullion amounted to 11% of its gross value. The poor extraction and the high imposts left but a small margin of profit. A search for better metallurgical treatment was undertaken. The cyanidation tests made by Leonard Holms in 1901 did not seem to

justify turning to that method at that time; subsequently, however, E. M. Hamilton made a new research on a working basis, with a 5-ton plant, and he obtained encouraging results. However, nothing was done for a year.

Meanwhile the recovery by amalgamation continued to dwindle and when cyanidation was re-commenced, there was a fear lest the further change in the ore with depth might affect extraction by cyanide as it had done that by mercury. In 1904, Bernard MacDonald was engaged to investigate the problem, with the idea, among others, that the Hendryx process might be applied. Complete cyanide tests were made and every kind of ore in the mine was tried. The results fully confirmed Hamilton's earlier work, even on the ore from the bottom of the Sirena mine. It was demonstrated that finer grinding was required and that even the concentrate, if ground dry to pass through 200 mesh, would yield 94 to 96% with the use of a 2.5% cyanide solution—a solution unusually strong, but based upon the relative proportion of silver to be dissolved. A weaker solution would have done better, as was proved later.

In these tests, a fresh solution was introduced each 24 hours into bottles that were agitated by being attached to the periphery of a slowly revolving wheel. This failed to reproduce working conditions, because it eliminated a drawback inevitable in practice—that is, foul solutions. For this reason the

results were higher than was to be expected in the mill, but they warranted the belief that a plant specially designed for the treatment of the concentrate would yield larger profits than the sale of the concentrate to the smelters. The tests demonstrated also that the silver sulphide was readily attacked by cyanide when the grinding was as fine as 200 mesh. As yet, no plant has been erected to treat the concentrate, but it is likely that this will be done.

In the meanwhile—this was in April, 1904—it was decided to erect the existing cyanide plant, which started to work in May, 1905. When concentration was made to precede amalgamation, the grinding in pans was discontinued, it being found that amalgamation was more effective in charges than as a continuous process. In erecting the cyanide annex, the only change required was to divert the flow from the Wilfley tables to cone-classifiers. The coarse sand went to a tube-mill of Allis-Chalmers make, 5 ft. diam. and 22 ft. long. It was lined with chilled iron, which, after a three weeks' run, collapsed, so that the use of the tube stopped abruptly. It has not been employed since. Tests proved that the benefit of the re-grinding in the tube hardly warranted the extra expense of repairs and power. The first cone-classifiers were discarded, the pulp going from the Wilfleys to a set of cone-classifiers that separate the sand from the slime. The arrangement is shown herewith, in Fig. 22. *A* is a large spitzkasten, 8 ft. wide and 8 ft. deep, the classification

being by gravity. The sand, plus some slime, flows through rubber goose-necks to a height two feet above the bottom into four smaller cones or spitzlutten, 4 ft. wide and 4 ft. deep, equipped with hydraulic jets. The undersize from all five cones

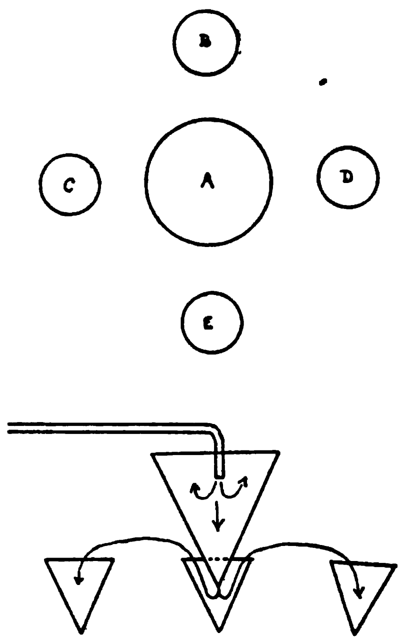


FIG. 22. ARRANGEMENT OF CLASSIFIERS.

unites and flows to eight Callow steel settling-cones, 8 ft. diam. and 8 ft. deep, where it is de-watered. Thence the pulp passes to three masonry vats, where lime is added to effect settling previous to decantation, and at the same time destroying the acidity of

the slime and bringing the positive alkalinity up to 1½ pounds of lime per ton. Then this slime is pumped to the treatment-vats, the sand meanwhile going to collecting-vats, from which, after draining, it is taken in cars to the treatment-vats.

This was the scheme at the commencement of cyanidation; subsequently, the masonry vats, formerly employed in de-watering the pulp previous to pan amalgamation, were modified so as to serve for holding and thickening the slime. The five cone-classifiers were moved into the stamp-mill, in order not to lose grade, and in this new position they delivered direct into the masonry vats behind the old amalgamation pans, the vats built in the cyanide annex being used for the same purpose, namely, to de-water the slime. Even now it contains 70% water, and this 70% is just so much liquid that has to be displaced by the effective cyanide solution, until perfect diffusion is attained.

The ore goes from the Sirena mine to the mill in cars (Kilburn & Jacobs) of 50 cu. ft. capacity, carrying 2.4 tons each. They have a double side-dump, with gable bottom, and appear to work easily. Waste is removed by sorting in the big courtyard at the entrance of the main adit. A sorting belt is to be used at the new Soledad shaft, the waste thus eliminated being returned into the mine as filling. The belt is to be 50 feet long, giving room for five men on each side, and it will be illuminated by shaded electric lights like a billiard table. Each man is to

sit astride a wooden horse, which is high enough to give freedom of reach over the belt.

Gold can be seen in the surface ores of the Sirena mine; it accompanies the argentite. Pyrite does not appear to be indicative, nor is it a close associate of the precious metals; it is more plentiful in the undigested country rock. In the ore of the Peregrina mine there is a little arsenical pyrite and also traces of antimonial silver minerals. At Guanajuato generally, the average yield of concentrate does not exceed two per cent, carrying 150 to 1,600 oz. silver, and from 1 to 30 oz. gold per ton, so that the problem is to treat a small quantity of high-grade material in competition with the excessive freight-charges of the railroads and the heavy treatment-rates of the smelters. Further, the Government tax is one per cent less on bullion than it is on the precious metals when in the form of concentrate.

In September, 1905, the mill treated 3,887 tons of ore, containing 517 grams of silver and 2.76 grams of gold per ton. On leaving the concentrators the pulp assayed 302.5 gm. silver and 1.46 gm. gold. The concentrate recovered amounted to 106 tons, averaging 948.06 gm. silver and 46.92 gm. gold. The cost of crushing and concentration amounted to 1.75 pesos per ton. The extraction by concentration was 50.1% of the silver and 49.1% of the gold.

The practice is still in course of development and experiments are continually being made. Re-grinding does not seem required by the Sirena ore; it is

stamped through a diagonal slot screen equivalent to 40 mesh; a chuck-block is used. Of the resulting pulp, 80% goes through 100 mesh. The granular quartz, when crushed, readily liberates the silver sulphide, but the chalcedonic gangue in which the silver occurs (in a cloudy dissemination like moss-agate) needs fine grinding—all of it—to pass at least 100 mesh. The concentrate carries 30% silica; the portion that passes through 200 mesh represents 15.5% by weight and as it is worth 398 pesos per ton, it contains 42% of the assay-value of the ore.

In watching the agitation in the slime-vats, it was noticeable how the circular motion becomes accelerated until the moving mass of pulp and solution advances faster than the paddles. On starting the agitation, one can see the sinuous streaks of clear cyanide solution in the slime, and this condition of imperfect dispersion is never wholly overcome; it is due to the resistance of slime to diffusion. I noticed this appearance (or phenomenon) in a vat that had been at work for 40 minutes. Another note; even ten minutes after the agitator is stopped, the movement of water at top of the vat continues in the direction started by the paddles. Two pounds of lime are added per ton of solution in order to hasten settlement of the slime. The effects produced have been discussed in connection with milling at El Oro.

The loss of sodium cyanide at the Sirena mill is 4.12 pounds per ton of crude ore, while the consumption of lime is at the rate of 6 pounds, worth 12 pesos

THE HACIENDA SAN FRANCISCO DE PASTITA

A Glimpse of Guanajuato Through a Hedge of Organ Cactus

per metric ton. Sodium cyanide costs 15¼ cents per pound delivered at Marfil station, the present terminus of the Mexican Central railroad; this price is on the basis of 100% cyanide, but as sodium cyanide contains 128 to 130% cyanide, the cost is actually a little over 19 cents per pound; to this must be added 1.25 pesos, or, say, 60 cents per ton, for transport to the works, making the total cost about 19½ cents per pound.

There is always some re-precipitation when treating silver sulphide, by reason of the formation of potassium sulphide, but this is diminished by the addition of lead acetate, which forms a plumbous hydrate that removes the soluble sulphides by forming a lead sulphide and the potassium or sodium hydrate. In practice, the re-precipitation of silver is surpassed by the re-dissolving of it in the cyanide solution.

By passing through cone-classifiers the product escaping from the upper mill is divided into 'sand' and 'slime,' which are treated separately, or in the cyanide annex. In the 'sand' department there were 20 vats, each containing an average charge of 2,651.7 cu. ft., or 89.6 tons. During the month 1,792 tons (dry) of sand was treated. The average assay-value before treatment was 297.5 gm. silver and 1.37 gm. gold; after treatment the contents were 52 gm. silver and 0.1 gm. gold. In the 'slime' department there were 82 vats, each containing 3,851.8 cu. ft. of wet slime, equivalent to 24.26 tons dry. During the

month, 1,989 tons were treated. The average assay-value before treatment was 275.5 gm. silver and 1.3 gm. gold. After treatment the assay became 45.5 gm. silver and 0.1 gm. gold. The extraction was 85.1% as regards the silver and 70% of the gold in the pulp treated by the cyanide annex, the total recovery by cyanidation being 41% of the assay-value of the crude ore, so that the combined extraction by cyanidation and concentration was 91.2 per cent. The total cost of cyanidation was $4.13, and the consumption of cyanide 1.9 kg. per ton.

Note should be made of the fact that successful experiments with cyanide on silver ore had been made earlier at the mines in Sinaloa, but the results had not been heralded because they were obtained at private properties, and even in these cases the official tests of the cyanide company at Mexico City had discouraged hope. The trouble was due to the use of too weak a solution—a swing of the pendulum in cyanide practice, for in its early days the main fault was the employment of a needlessly strong solution. Another factor that prevented success with these silver ores, was the insufficient time given for chemical action. The element of time is especially important in the case of concentrate, that is, iron pyrite carrying gold free and silver as argentite; the millman can afford to give the time required because of the small quantity of this product and its richness.

Chapter 31

METHOD OF TREATMENT IN THE BUSTOS MILL—CONVEYING THE TAILING BY PIPE—THE STAMP-MILL—CYANIDE PRACTICE—COMPARISON WITH THE PATIO PROCESS.

REFERENCE has been made to the milling practice of the Guanajuato Reduction & Mines Company in speaking of the Bustos plant. It deserves further consideration. Although the property was acquired in January, 1904, it was not until February, 1905, that it was decided to build 80 stamps, rushing the erection of five of them so as to afford experimental data during the construction period. Many tests, on a large as well as a small scale, had already demonstrated that a high extraction of both silver and gold could be obtained from the ore by cyanidation, and the experimental plant became of great service in testing ores from different parts of the company's properties, as well as to suggest the detail manipulation best adapted to the main plant, then under construction. The mines are a mile from Guanajuato, and there are no streams available for disposing of the tailing; nor is there the space necessary for accumulating residue on a large

scale. It became necessary to discharge the tailing into the main stream of the district one mile from the mines, and this meant the transport of all ores through the heart of the City over an expensive railroad system, or the complete separation of the stamp-mill from the cyanide plant, the latter to be placed upon the main stream.

The Homestake system, of conveying the tailing in a cast-iron sewer-pipe, was adopted; it is an 8-in. water-pipe of bell and spigot type, asphalted, laid for its first few hundred feet at a grade of 3%, then flattening to 2¼%. As it was desirable to settle and return for re-use as much of the water coming from the concentrators as possible, allowing the thick pulp only to pass through the pipe, and to determine to what point such thickening was possible, several hundred feet of the pipe to be employed in this work were put together and laid out upon the actual grade. Arrangements were made to circulate any given quantity of sand (crushed in the stamps of the experimental plant already installed) through this pipe-line at any desired degree of dilution. Pulp was first tried at a normal dilution of 8 of water to 1 of sand, just as it came from the tail of the concentrator tables; the water was then decanted by successive steps, thickening the pulp, and several runs were made under these varying conditions. It was desired to remove a maximum of one-half of the original water, and in the experiments the 8 to 1 pulp was reduced to 2.5 to 1; and so successfully that not only

was the pipe not clogged with sand, but the pulp at that thickness had such rapidity of flow that it readily carried cast-iron nuts and other heavy objects without interrupting the stream. Tests made by Mr. Carlos Van Law prove that pulp which has passed through a 30-mesh screen, with water in the proportion of 7½ to 1, will flow through a launder of square cross-section, made of rough boards, set on a grade of 1½%. With a V-shaped wooden launder, such pulp will flow at less grade and with less water. The area of the wet perimeter is the chief factor.

This problem settled, the process was outlined as follows: The ore is transported over a railroad from the mines in hopper-bottom cars, which discharge into a large bin at the crusher plant. It is then reduced by a No. 5 D. Gates crusher to 2-in. size, discharging over a picking-belt for removal of waste, then re-crushed by a short-head No. 4 Gates crusher to 1-in. ring, then removed by conveyor-belts to the mill-bins, where it is distributed by cars, this (owing to cheap labor) proving more economical than the use of a system of conveyor-belts over the top of a bin with automatic trippers. The mill-bin has a capacity for five days, which, together with the large bin at the crusher plant, affords sufficient storage of ore.

The ore is then crushed under eighty 1,050-lb. stamps of Allis-Chalmers make. The mortars are set on a concrete foundation, the anvil-block being cast as an integral part of the mortar. The latter has a

steel liner, two inches thick, but there is 13.5 inches of metal below the liner. Between the anvil-block and the concrete a quarter-inch sheet of rubber is spread. The mortar has a broad base—36 inches wide—provided with strong ribs at the sides.

The 30-mesh pulp resulting from the stamping is concentrated over Wilfley tables, a considerable amount of middling produced being removed for re-grinding in an Abbé tube-mill and subsequent treatment over separate concentrator tables. The tailing from all the machines drops into concrete launders and passes to the cones, where about half of the water is removed for use in the mill. The thickened tailing then enters an 8-inch cast-iron pipe, laid with the gradient above mentioned, and goes to the classifiers in the Hacienda Flores, situated upon the main channel of the Guanajuato river. The classifiers are all of the Homestake type, two sets of cones being used, the lower one taking the bottom product of the upper. The overflow from both sets of cones goes to the slime plant, the lower cone having an ascending current of water.

The sand coming from the bottom of the lower cones is distributed, by the Butters & Mein device, into either of two receiving-vats, each of 350 tons capacity. These were planned to serve an ultimate capacity of 500 tons daily, with the slime separated.

The receiving-vats are alternately filled and drained, the discharge being made through bottom gates onto ascending conveyor-belts, which pass over

Pipe-Line for Conveying Tailing

Capt. Narváez

Tube-Mill at Pachuca

A Mexican Family

One Girl Grinding Corn; Another Baking Tortillas; Mother Nourishing Infant and Father Doing Nothing Gracefully

the centre of the line of eight leaching-vats, each of the same size as the receiving-vats. In these a 14-day treatment is given with 0.5% cyanide solution, the sand being then washed and ultimately discharged on conveyor-belts (running under the vats), which deliver either into the river during the rainy season, or to elevated storage-piles during the dry season, to be sluiced during the succeeding rainy season.

The slime from the classifying cones is treated by agitation with mechanical stirring and large centrifugal pumps, which draw from the bottoms of the vats and discharge over the tops, the total time of treatment being four days. After the final wash the slime is pumped into settling-vats 30 feet high, where a further decantation occurs before the slime is discharged, with a very small percentage of moisture, into the river.

The entire plant, both the stamp-mill and cyanide annex, is designed so that it can be doubled, when the stamp-mill will take a back-to-back form, 80 stamps with their concentrators being on either side of the bins. The classifying-cones and the receiving-vats of the cyanide annex are of sufficient size already for a 500-ton plant, it being necessary only to add another line of eight leaching-vats and the corresponding slime-vats to bring the cyanide plant to the larger capacity mentioned.

For roofing, corrugated galvanized iron on a steel frame is preferred. As there is no load of snow to fear, it is possible to use a light roof-truss. The

native tile is cheaper, but it requires a heavier construction, and does not afford as complete protection. The Northerner will remark the lavishness of the masonry about the mines and mills in Mexico. It is the cheapest kind of construction and the native wood is usually poor; it will twist and untwist as the dry and wet seasons succeed each other, making it an unsatisfactory structural material.

At the time of my visit there were 120 stamps in operation in the Guanajuato district, and there were 205 tons being treated daily by cyanidation and 25 to 30 tons by the Patio process. Thus does the new drive out the old. In 1887 there were 34 *patios* at work; now there are only two.

In regard to cost in the Patio process, I have the following data from the Hacienda de San Julio at Pachuca:

	Pesos.
Crushing, to pass 60-mesh in Chilean mills, with overflow discharge..	3.60
Maintenance	0.50
Salt. 5%, or 50 kg. per ton	1.75
Copper sulphate. Loss, 0.5%	1.25
Mercury. Loss, 1½ kg. for each kilogram of silver	4.38
Transport from the mine	1.08
Total	12.56

The ore is bought on the dump, therefore the cost of transport is included. Salt costs 35 pesos per ton; copper sulphate, 250 pesos per ton; and mercury, 3.41 pesos per kilogram. The average losses for the year were 1.18 to 1.50 kg. per kilogram of silver extracted; the loss of silver being 6.13 to 10.92% on the clean ore, and 15.83 to 29.13% on the galena ore. The Patio

process waits on the completion of the chemical reactions, and it is therefore continued until extraction ceases. Time is not considered; in winter it requires 20% longer by reason of the lower temperature of the air.

At Parral, in Chihuahua, with the Russell process, using hyposulphite, the cost of lixiviation and roasting is 11 pesos, but the recovery is not as high as it is with amalgamation on the *patio*, where the cost is 11 to 14 pesos, varying according to the manganese content of the ore.

At Pachuca, by Mexican methods, the cost of mining and sorting ore amounts to 15 pesos per ton; the transport to the *patio* and the treatment there add a further expense of 14 pesos, not including losses or the expense of marketing the product. By stamp-milling, pan amalgamation, and concentration, the cost at Guanajuato was 8 pesos; and now by stamp-milling and cyanidation the cost is 5.85 pesos. That of mining and development is 3.50 to 4.50 pesos, so that the total present cost is about 10 pesos, or $5 per ton.

At the time of my visit there were about 200 men, women, and children in the Anglo-American colony at Guanajuato, the American element predominating. Of the 125 men employed, 75 to 80 were technical men, of good training. This made a strong piece of mental machinery for industrial development.

Chapter 32

OLD METHODS—AN ABANDONED ARRASTRE—THE HACIENDA DE ROCHA—MEN AND MULES.

XAMPLES of old methods of engineering, now becoming displaced by the aggressive inroads of technical science, are afforded by two photographs that are reproduced on the accompanying pages. One shows a Mexican drawing water by the aid of a mule operating a lantern-gear wheel. In the foreground is a channel, made of cement, along which the water is directed for purposes of irrigation. The *adobe* walls and pepper tree (*perul*) are typical of Mexico. In front of the well there are two women, one of whom is washing and the other gossiping. It was ever thus.

On another page there is a photograph of some old machinery at San Francisco, in the State of Michoacan, and about seven miles from El Oro. In the foreground is the pit of an *arrastre;* the cords that attached the mullers or grinding stones to the revolving arms of the machine are easily distinguishable. The cord or *riata* is made of grass fibre, although for this purpose leather thongs are more usual. Motive power was obtained through the wooden spur-gear operated by a water-wheel within

Water Wheel and Irrigation Method

An Old Arrastre

the building, the wall of which forms the background. The water-wheel is 20 feet in diameter and carries a pinion that gears with the crown-wheel on the vertical shaft of the *arrastre*. One of the discarded (because worn out) grinding stones lies in the sunlit foreground.

As the Patio process is surely destined to become obsolete with the introduction of more rapid (and therefore cheaper) methods of metallurgical treatment, it is worth while to preserve an accurate record of this old method of extracting silver from the ore. By courtesy of Mr. Bernard MacDonald, I am able to reproduce the plates accompanying a report made in 1866 by E. Tillmann, the Royal Commissioner of Mines. This Prussian officer had visited Guanajuato in 1865 at the instance of his own government to examine the mining practice then obtaining in the most progressive parts of Mexico.

The plate opposite page 250 gives a photographic view of the Hacienda de Rocha and a plan of the establishment, the various departments of which are indicated by letters, with an explanation in Spanish on the margin. This is a good example of an old *hacienda de beneficio*, the mechanical details being illustrated in five spirited drawings, all of which are here reproduced. Fig. 23 shows the stamp-mill, with wooden stems (*b*, *b*) shod with iron (*c*, *c*), resembling those generally used in Mexico until recently. The motive power is obtained from four mules harnessed

FIG. 24.

to the long arm (*k*) of a whim or *malacate*. The teeth of the interlocking wheels are made of wood.

After being crushed under the stamps, the ore is passed to the *arrastre* exhibited in Fig. 24. Here the fine grinding was done. The mules are again in evidence. The bed of the *arrastre* consists of stones placed on end and the muller or upper grindstone (*t*) is hung by chains (*g*) or leather thongs from the radial arm (*e*) extending from the pivotal axis (*a*). When it had been reduced to a fine pulp by the *arrastre*, the ore was allowed to settle and thicken before being taken to the open yard or *patio* where it was mixed with *magistral*, salt, and quicksilver, as we have seen at Pachuca. After being exposed to the air and thoroughly mixed by the tread of squads of mules, it was conveyed to the settling-vats shown in Fig. 25, where it was thinned with water, so as to allow the amalgam to separate and accumulate on the bottom. Then the amalgam was distilled in an iron retort of the shape indicated by Fig. 26. This resembles the one seen in the Hacienda La Union, at Pachuca, and described on a preceding page. Finally, in the last drawing (Fig. 27) there is an excellent representation of the manner in which the cast-iron hood was raised when the distillation of the mercury was completed, disclosing the sponge of silver that remained in the retort. This silver was melted into bars.

"By the wayside of progress lie the broken images of the past."

Typical Hacienda de Beneficio or Reduction Works

Fig. 26.

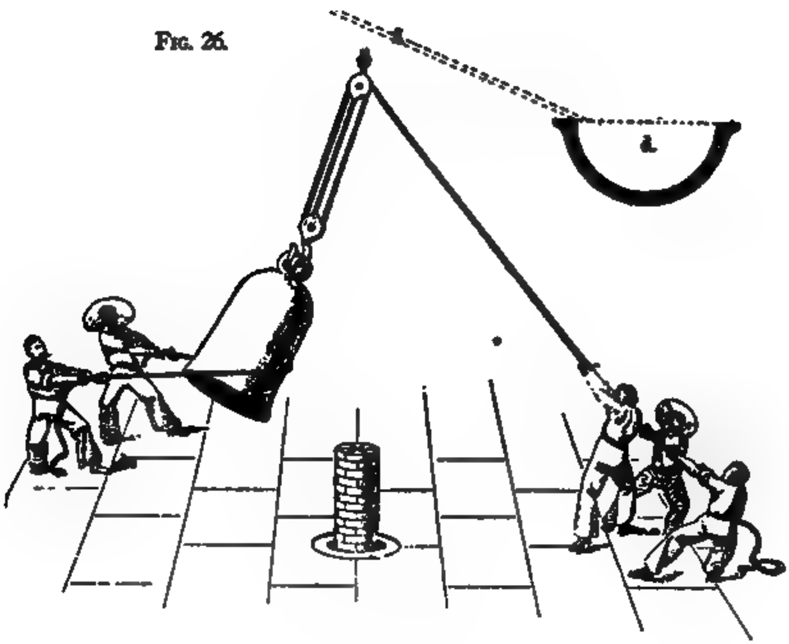


Fig. 27.

Chapter 33

THE FLOOD AT GUANAJUATO—THE HUMOR AND THE TRAGEDY OF IT—CONCLUSION.

GUANAJUATO had a flood, and like that of Noah, it serves as a new starting point in local history; things happened B. F. or A. F. The catastrophe occurred on the first and second days of July, 1905, so that the recollections of it were still vivid at the time of my visit. Unusual tropical showers poured upon the neighboring country, and the waters converged from a steep watershed into a narrow ravine choked by bridges and crowded with dwellings. Never wide, the bed of the Guanajuato river had been elbowed by roads, houses, and débris, so that in places there was left a channel only two metres deep and four metres wide. Furthermore, it was extremely tortuous, the original course of the river having been repeatedly diverted to secure space for buildings. On the first day, the water rose to a level which just exceeded that of the flood of 1873—about four feet above the street. On the second day the volume of water doubled, it rose 15 to 17 feet above the pavement, and made terrific havoc among the soft masonry and mud walls of the old town, which melted like salt before the onrush. A few

minutes sufficed to cause the collapse of many buildings, and to create fearful confusion. At that time a sewer was being constructed at the upper end of the town, near the Presa, and the timbers of this were torn out, to be carried forward so as to form a battering ram, demolishing the *adobe* walls and choking the confined channel of the torrent. Officially it is stated that 54 were killed, but 73 were carried to the morgue, and it is probable that fully 100 people perished. Many Mexicans from the outside country happened to be visiting the town, it being the time of a *fiesta*, and of these a number were never accounted for. No Europeans or Americans were drowned.

At the time, there was nothing humorous about the disaster, but, with that happy instinct of humanity, as the horror was forgotten, some of the absurdities were remembered. To the natives it was an opportunity for spoil; looting was general. "*Es un regalito de Dios á nosotros que no sabemos trabajar*"—"it is a little gift from God to those of us who don't know how to work," so they said to themselves. Some of the *peones* laid their hands on a shoe-store that had been devastated, and to this day they can be seen wearing a tan shoe on one foot and black leather on the other. The pink and green steamer-trunks of an American lady glorified the torrent for a while; they bobbed under the arch of a picturesque bridge, and landed in the second story of a needy native. A mule was borne by the flood into another second story, and in his terror he bit into a box of Ivory soap,

and it was this that buoyed him across the waters. Billiard tables, with their slate tops cruelly exposed, were engulfed in the whirling débris. Seventeen pianos and two cannons meandered down stream to the sound of many waters and their own spontaneous accompaniment. An azure splendor suffused the scene as a box of bluing from a laundry made its vivid passage; whereupon the pianos played a familiar waltz of Strauss. Bolts of silk appeared among late mules and defunct pigs, street-cars were seen with men balancing on their unsteady decks until the upper windows of a church offered shelter. The Teatro de Juarez received a complement of burros, and the compliment of their lamentations, which simulated grand opera, just as the sequel imitated Noah's Ark, for when the waters subsided, they made their timid descent down the grand staircase with all the dignity befitting a momentous occasion. But worse things than these happened; a case of Saratoga whisky floated onto the desk of a total abstainer—and the owner of the whisky never saw it again.

With the downpour of rain came darkness, the natives lit candles, and the women came out on the balconies with lights, wherewith they made the sign of the cross, the church bells were rung, and to the natural horror of the scene was added a touch of solemnity. This was on the first day; when the second flood came in the late afternoon of the second day, with its repetition of an uncanny darkness, the people crowded to the adjoining hilltops, which

Scenes in Guanajuato after the Flood

Plazuela de San Pedro, Guanajuato

The Flood Rose to the Lettering of El Trafico. Note the Donkeys Laden with Plank

were brilliantly illuminated with moving candles, while the air vibrated to a thousand bells. To them it was the end of the world, and we, of San Francisco, who saw a greater devastation, can well imagine that to their simple minds it seemed a horror beyond explanation.

And so I come to the end of the notes that record my recent travels in Mexico. To speak in the language of photography: I brought some films from Mexico; most of them were only snapshots, there being no opportunity to get time exposures; therefore the images that I have delineated, and the impressions that I have tried to convey, may lack definition. But beyond the mental imprints which it has been my endeavor to transfer to the pages devoted to this account of a journey in the southern land, I brought other memories and experiences, which were never developed; they remain blurred, and to none but myself have they a meaning. I have recollections of multi-colored façades, of sunlit walls, and cool *patios*, the sound of bells, and the cracking of whips, cries of *cerveza* and *frijoles*, conical hats and hooded women, a stream of chocolate-colored humanity, a politeness that gave dignity to the commonplace, a squalor that soiled romance, and a sunshine that glorified everything; and then, like the refrain of a song that we love, the kindness of the men of my own race, and the hospitality of women who make every abiding place a home. And so, *Vayan con Dios mis amigos*.

Across the San Juan Mountains

Being the account of a ride over the mountainous mining regions of Southwestern Colorado, in September, 1902. Reprinted by permission from The Engineering and Mining Journal.

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Across the San Juan Mountains

Chapter 1

THE START FROM OURAY—VISIT TO THE AMERICAN NETTIE MINE—CLASTIC DIKES—A PICTURESQUE TRAMWAY.

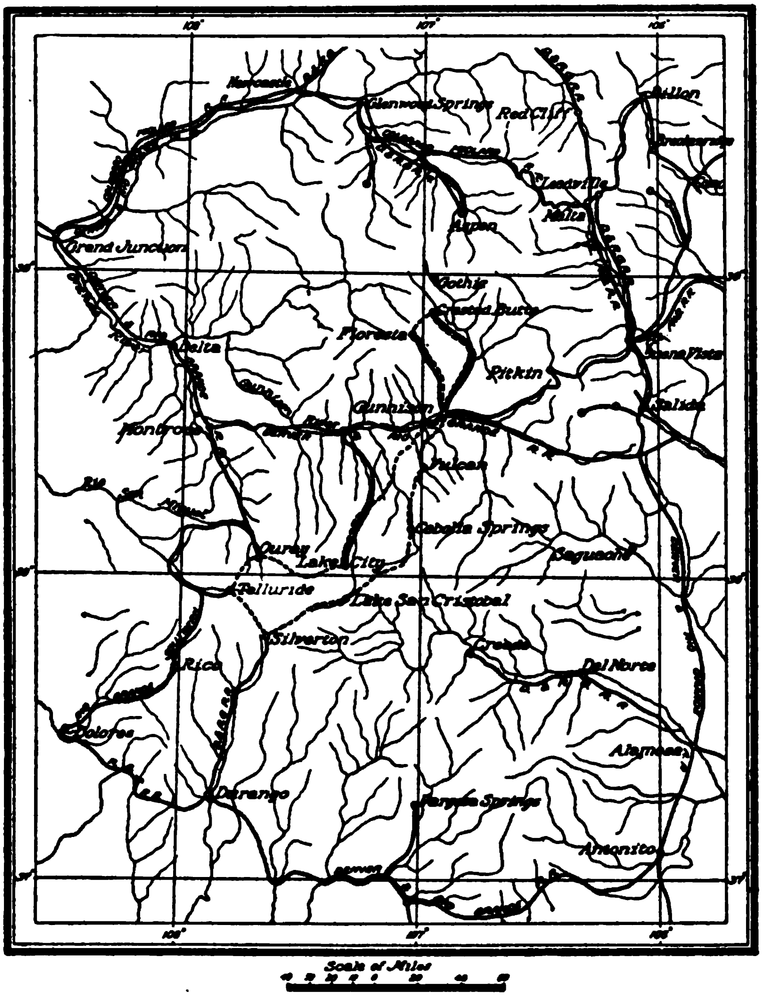
N a superb morning in September, that month of many colors, four of us[1] started on a ride among the mining districts of the San Juan in southwestern Colorado. The starting point was Ouray, the picturesque little town named after the old chief, an Indian of renown, the friend of the white men that first explored the mountain fastnesses of the Uncompahgre. From Ouray we rode across the ranges to Telluride, Silverton, Lake City, Gunnison, and thence to Crested Butte and back, following a course which,

[1] The party consisted of H. N. Tod, Lionel Lindsay, C. H. Wittenoom, and the writer.

on the map, looks like a figure 8, with Ouray at the base of the lower loop and Crested Butte at the top. See map. The distance was slightly over 400 miles; the country traversed is beautiful to the traveler and interesting to the mining engineer, so that the experience was sufficiently rich in incidents and information to warrant the account which it is my purpose to present.

We left Ouray early on the 5th of September, 1902, with the intention of visiting two mines in the vicinity—the American Nettie and the Bachelor. A mile below the town the trail ascends the precipitous sides of Gold hill, and as our sure-footed mountain horses followed the zig-zag through the pines we found that each turn of the trail brought a steadily expanding vista until, halting on a projecting rock, we could see far out toward the north to the tablelands behind Montrose, across the near valley to the terraced dip-slopes of Triassic sandstone, down upon Ouray itself, cradled amid red rocks and golden aspens, and up beyond the town to the sentinel peak of Mt. Abram, which guards the sources of the swiftly flowing Uncompahgre.

On arrival at the American Nettie mine, the superintendent, Mr. Kunz, permitted us to visit the underground workings. These have an aggregate length of 12 miles, and consist of a series of adits and drifts penetrating the top layers of the Dakota sandstone where it comes in contact with the overlying black shale of the Colorado series. Both formations


Glenwood Springs
Red Cliff
Dillon
Leadville
Malta
Aspen
Grand Junction
Gothic
Crested Butte
Floresta
Pitkin
Buena Vista
Salida
Delta
Gunnison
Montrose
Vulcan
Cebolla Springs
Saguache
Ouray
Lake City
Telluride
Lake San Cristobal
Silverton
Del Norte
Rico
Dolores
Alamosa
Durango
Antonito
Scale of Miles
Route followed

are members of the Cretaceous, the Dakota being the basal member of that division. The ore is found in irregular masses occupying chambers in the sandstone and impregnating the rock along stringers or small veins, which serve as a guide in prospecting. In the cavities the ore consists chiefly of a sintery mass of oxidized material, earthy and red, but when the ore is found impregnating the body of the sandstone it appears in the form of sulphides—iron and copper pyrites, blende, galena, and gray copper. The

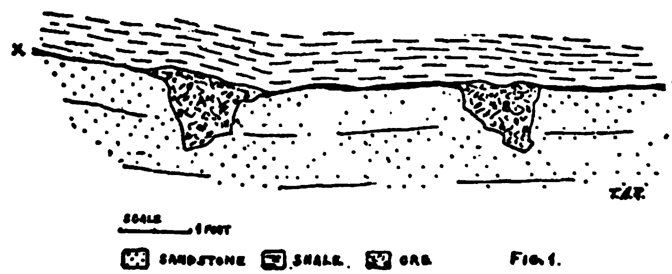


Fig. 1.

best ore seems to hug the contact with the overlying shale, in the manner illustrated in Fig. 1, where *A* and *B* are 'pockets' of ore reaching downward from the shale-sandstone parting and connected by a seam *X Y*, which follows the line of division between the two rock formations. The pockets are full of crumbly oxidized ore intermixed with a little gypsum, while *X Y* also carries some gypsum and a thin layer of black crumbly lime-shale, which suggests that it originated from the dissolution of an impure gypsum. The bedding is flat, with a slight dip to the northeast,

The Amphitheatre of Ouray

The American Nettie Mine, near Ouray

and the formation is crossed by almost vertical dikes which have evidently been the immediate cause of such fracturing of the sandstone as was favorable to subsequent ore deposition. In prospecting, it is found best to follow stringers of pyrite or even mere 'walls' (slight fractures devoid of ore) that are parallel to the course of the dikes.

These dikes are peculiar; they are not made up of volcanic rock; on the contrary, they consist of clastic[2] material, that is, fragments of sedimentary rock; in the American Nettie mine the fragments were recognizable as pieces of sandstone, probably derived from beds not far away. The dikes that we saw were 2 to 4 feet wide, and were well defined by their distinct walls; the country near them was fractured and sheeted, a condition probably due to the disturbance brought about by the intrusions of volcanic rock, which are known to occur in certain parts of Gold hill. Not that the clastic dikes are of direct volcanic origin—quite the contrary; they are built up entirely of sedimentary rock material, which has been packed together and cemented by the water that has found its way into them; they occupy fractures that may have been, and probably were, the indirect result of an intrusion, through the neighboring formation, of true eruptive matter, such as has been referred to as actually occurring near-by. On the high ridge above the American Nettie mine there is a coarsely porphy-

[2]From the Greek, *klastos*, broken. It is employed to describe rocks made up of fragments, as distinguished from the crystalline.

ritic diorite, which suggests an agency capable of having brought about the fracturing that led, first, to the formation of the clastic dikes and, subsequently, to the circulation of the ore-depositing waters.

The American Nettie has a new tramway, whose catenary curve sweeps from the high cliffs of Gold hill, and, with undeviating line, bridges the abyss of the valley. It is a picturesque bit of engineering. A descent of 1,820 feet is made in 4,200 feet. The span that crosses the valley is 2,100 feet long, and in that distance the drop is 915 feet. The engineers of the Leschen Company built it and, owing to the abrupt contour of the ground, they had to make especial provision for safety. The descending side has a cable 1⅛-inch diameter, while the cable upon which the empties return is one inch in diameter. The traction rope is ¾ inch. To the latter, button-shaped clips are permanently attached, with intervening spaces, the length of which is regulated by the number of buckets in use. The buckets are automatically detached and attached to the rope, at the loading and terminal stations; at both terminals the buckets receive a retarding and accelerating movement, as they arrive and depart, respectively, in order to diminish the vibration attendant on the removal of the load from the line, and the return of it into service.

Pack Train at the American Nettie Mine

Mules Laden with Lumber for the Mines

Chapter 2

THE BACHELOR MINE—TRAIL HORSES AND MOUNTAIN TRANSPORT—MINERS' COFFEE—A STRANGE DIKE—THE THEORY OF ITS FORMATION—DESCRIPTION OF THE LODE.

AFTER leaving the American Nettie mine we followed the trail that took us around the northern ramparts of Gold hill, down into the valley, whence a road led to the Bachelor mine in Red cañon. Two members of the party, who were unused to the mountain horse, marveled at his sure-footedness as we scrambled down talus slopes and threaded our way among loose blocks of fallen rock. It is my experience that a good 'trail horse' will go almost anywhere that a man can go without using his hands, while the patient *burro* (donkey) will walk safely over ledges which bring a tremor to the hearts of those who are not mountaineers. All the exploratory work of the Rocky Mountain regions was done by 'packing,' that is, by the transport of supplies and machinery on the backs of animals. Both mules and donkeys are used in this service. When the former are employed they are strung out in a line and connected by rope. A man rides the leading mule and guides the whole

cavalcade. Another man usually walks or rides in the rear. When *burros* (the word 'donkey' being rarely heard in the mining regions) are engaged in packing they are not tied together, but each goes loose, and the owner drives them like a flock of sheep, though differing from the latter in that they have learned, from the narrowness of the trails, to walk in single file when that is required for safety. A mule will carry 250 pounds up grade and 350 pounds down, while a *burro* can manage to carry an average of 200 pounds. The mule requires to be fed, but the *burro* can eke out a precarious existence on the scant grass of the mountain slopes, and for this reason he has been most serviceable to the pioneer and the prospector; if the camel be named 'the ship of the desert,' the patient long-eared friend of the miner might well be christened 'the porter of the hills.'

When we reached the Bachelor mine the noon-day meal was ready, so we accepted the invitation of Mr. George Hurlbut, the principal owner of the property, to take luncheon before going underground. It will not be out of place to refer to the food that miners get in localities like these; it is surprisingly good, as a rule, even at mines which are a couple of miles above sea-level and a corresponding distance from the main distributing points for provisions. The companies usually charge one dollar per day for board and lodging, where standard wages are $3 per shift. The fare which the miner gets three times a day is superior to that of the second-class hotel of

the neighboring mining towns and far better than that which is the daily portion of workmen in other countries. There is always one weak spot—the coffee; partly because it is not prepared immediately before being served and partly because it is made from adulterated mixtures, and largely because the average mine cook does not know the taste of real coffee—at all events, it is a concoction out of keeping with the excellence of the remainder of the miner's fare and much better adapted for staining floors or removing boiler-scale.

The Bachelor lode is closely associated with a clastic dike of peculiar character; the same lode follows the dike through the mine to the east, the Khedive, and to the west, the Wedge. Light-colored sandstone and shale, belonging to the upper subdivision of the Triassic, constitute the prevailing formation; their dip is slightly southeastward and they are crossed almost at right angles by a dike, which inclines a little to the north and follows a fault-fissure of small displacement. In the Khedive the sedimentaries form a low monoclinal fold broken by the dike-fissure, with an amount of dislocation so slight as to be difficult of measurement. The zinc-lead-silver lode of the mine traverses both dike and country. When small it usually follows one or other of the walls of the dike, and when enlarged it spreads out into both dike and country. The lode has a northing of 45 feet in 480 feet, but this is due not so much to the angle of the dip itself as it is the

result of frequent offsets caused by slips along the bedding-planes of the country. These do not fault the ore, because they antedate it, but they cause the vein to diverge to one side in accordance with the course of the fracture along which the dike first, and the lode-forming solutions afterward, found a passage. The ore frequently spreads out between the bedding-planes of the sandstone and shale; it is also found in seams following fractures in the outer country that appear to be sympathetic to the main fissure occupied by the dike and the lode proper. The dike is usually about two feet wide.

The dike, as seen in the Bachelor workings, is called by the miners, of course, 'porphyry,' but it consists of fragments of quartz, from sub-angular pieces as large as a thumb-nail to grains of sand, and of flat pieces of black shale; the latter are prominent, and give the dike-rock a distinctly mottled appearance, as the accompanying photographs[a] show. They vary in size from microscopic fragments to bits several inches long. Besides these the dike contains pieces of sandstone, often micaceous by reason of sericite. A characteristic of the dike-rock is the arrangement of the shale fragments with their longer axes parallel to the walls of the dike; this is more marked in some parts of the mine than in others, and it is usually most pronounced close to the walls. (See Fig. 2 and 3.) The latter form a distinct parting from the

[a] These photographs I owe to the courtesy of Mr. Ransome and the U. S. Geological Survey.

Pieces of the Clastic Dike in the Bachelor Mine. Natural Size

A Prospector and His Burros

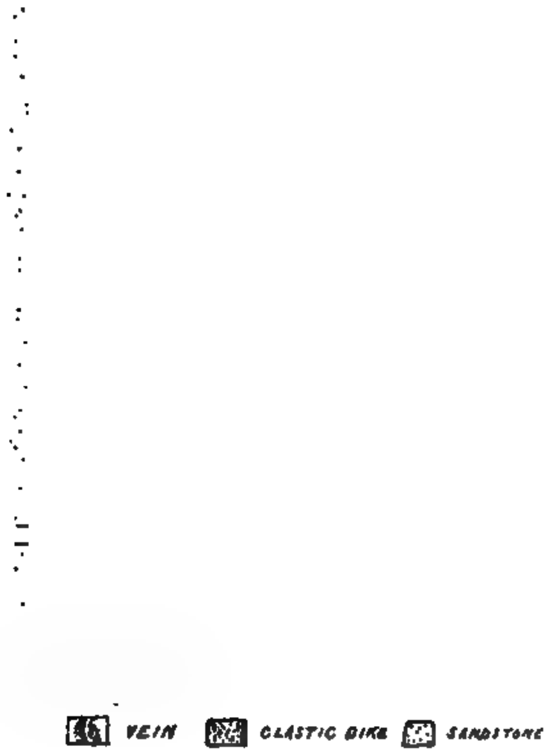


Fig. 2.

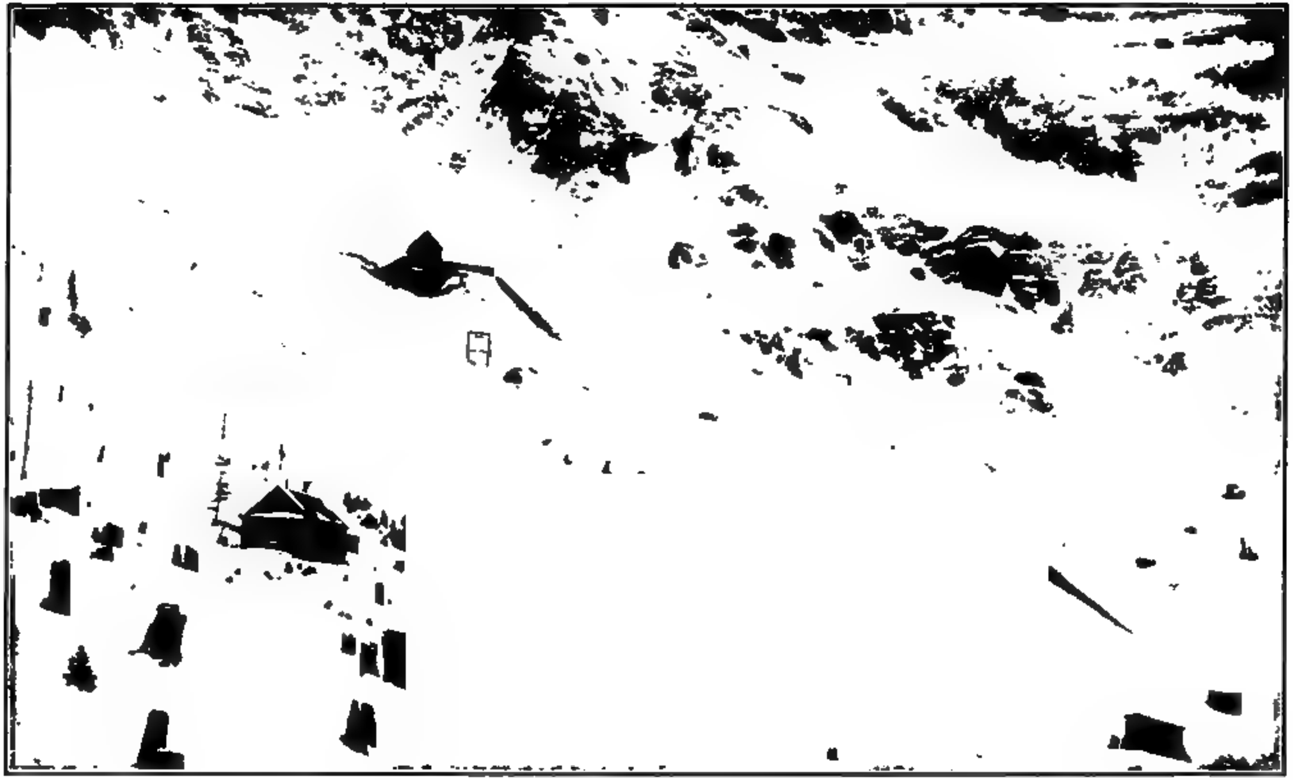
outer country, and sometimes are also accompanied by a selvage.

This, like the one we saw at the American Nettie mine, is a clastic dike and the origin of it affords good material for speculation. F. L. Ransome, of the United States Geological Survey, has contributed an interesting paper[4] on the origin of this very dike, and he explains it thus:

"A fissure was formed, accompanied by some faulting, and was filled, chiefly from above, by fragments of the soft fissile black shale, which does not occur in the stratigraphically lower beds exposed in the immediate vicinity, and partly by material from the lower light-colored beds forming the present walls."

That this pseudo-dike is built up of fragmentary sedimentary rock, that it occupies a fissure, and that it contains no lava or other volcanic matter as a cementing material—these facts seem to be assured. The nice point about the problem is the mode of formation. Was it from above or below? Mr. Ransome accepts the first alternative, and in support of this view he is enabled to instance the sandstone dikes that Whitman Cross found in the granite near Divide, in Colorado, that, elsewhere, Darwin, Ussing, Irving, and others have described, and ascribed to a filling from above. Hugh Miller found a pseudo-dike in Cromarty (Scotland) in which a mass

[4] 'A Peculiar Clastic Dike near Ouray, Colorado, and its Associated Deposit of Silver Ore,' by F. L. Ransome. *Transactions* American Institute of Mining Engineers, Vol. XXX., pp. 227-236.



Sunshine and Shadow on Snow. The Silver King Mine

THE CAMP BIRD MINE IN SPRING

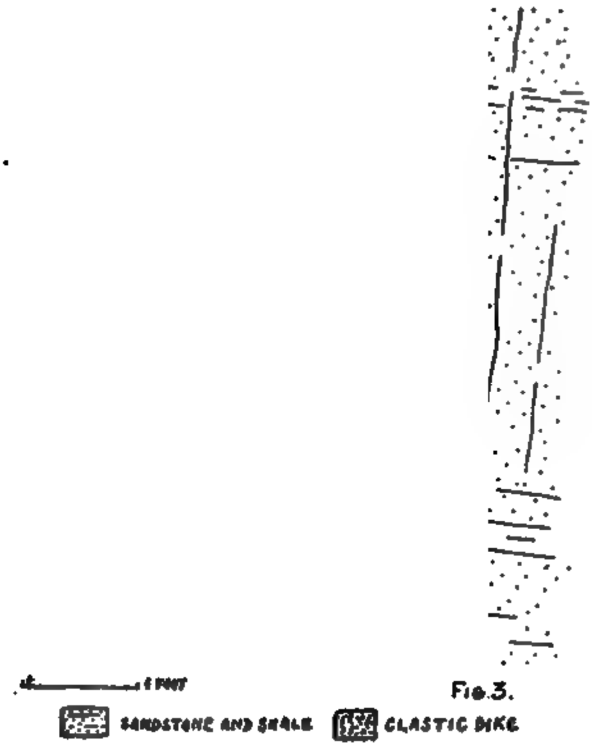


FIG. 3.

of sandstone working in from above (probably) contained fossils. Diller wrote a memoir[5] on the sandstone dikes of California and concluded that they were injected from below.

In the Lipari islands there occur masses of volcanic tuff, hard enough to be fractured, which exhibit cracks filled in with fallen dust and scoria.[6] But this is an entirely different kind of occurrence, as also is that observed at Pontgibaud (France), where a silver-lead vein occurring in granulite is shattered, together with its encasing rock, and, for a length of 10 metres, at a depth of 50 metres, contains boulders of scoriaceous lava evidently derived from the alluvium that once covered the outcrop of the vein.[7] It is obvious that occurrences of this kind, at surface or near it, are quite different in their origin from a clean-cut fracture many hundred feet underground, of great length and depth and persistent width. It is, however, worth while to emphasize the distinction.

As between filling from above by gravitation and filling from below through pressure, I am decidedly inclined to choose the latter. In the first place, no mining engineer familiar with the shifting of wall-rock would grant the idea of the maintenance underground of an open fissure, both large and crooked, in rocks so soft as these shales and sandstones, for a

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[5] *Bulletin* Geological Society of America, Vol. I., pp. 411-442.

[6] My authority is my friend, Professor John W. Judd, author of 'Volcanoes' and Dean of the Royal School of Mines, London.

[7] *Engineering and Mining Journal*, p. 151, August 18, 1894. 'The Lodes of Pontgibaud,' by T. A. Rickard.

Fig. 4.

period long enough to permit of the complete filling up of the supposititious *crevasse*. The sandstones and their alternations of shale exhibit movement along the sloping bedding-planes, as might be expected, and in the mine care has to be exercised to prevent injury from the rock that breaks off along these partings. Next, the internal evidence of structure appears to be against such a view. Fig. 3 illustrates a noteworthy characteristic of the Bachelor dike, namely, the frequent tendency to bulges and to vein-like protrusions, which extend from the body of the dike *upward* into the surrounding country. No downward filling would, so it seems to me, explain this condition of affairs.

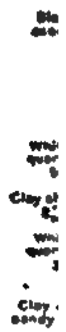
The fragments of black shale are traced by Mr. Ransome to an overlying bed through which the dike does not penetrate. Because it does not pass through this shale bed it is inferred that the latter was the source of much of the shale scattered through the dike. But why should not a simpler explanation suffice? Namely, that the fissure occupied by the dike broke through the harder sandstone series and died out when it met the tenacious, shifting, and more flexible layers of shale, much in the manner observed in the Enterprise mine. (See Fig. 4.[8]) Finally, it is said that the black shale does not occur in the lower beds observable in the vicinity of the mine

[8] Taken from *Transactions* American Institute of Mining Engineers, Vol. XXVI., p. 944. 'The Enterprise Mine, Rico, Colorado,' by T. A. Rickard, pp. 906-980.

workings. I thought so too, until, on the occasion of my second visit, I noticed an exposure of black shale near the roadside at a point a short distance below the Bachelor mill, and, presumably, not much deeper than the present workings of the mine. This points to the probability of there being other layers of black shale within the sandstone series traversed by the dike and renders it unnecessary to go far afield for a possible source of the black slivers so characteristic of the clastic rock. May it not have happened, therefore, that the dike was formed by the crushing of sandstone and black shale along the line of a fissure which was filled with this material as the fissure was slowly formed, much as water rises into a crack through the overlying ice? The close packing of the material within the dike, as is indicated by the arrangement of fragments of shale parallel to the walls, is indicative of subsequent pressure, and it is not without a further suggestion that greater pressure, but from below, may have originally pushed the clastic material upward into the fissure as it was formed. Water may have been present to give additional mobility to the broken matter, such water subsequently having been largely expelled by the squeezing in of the fissure-walls. Professor J. W. Judd examined some specimens of the Bachelor dike which I sent to him, and he concluded that the consolidation of the fragments was due largely, if not entirely, to the later chemical action of percolating solutions. To this suggestion there is the evidence

afforded by the subsequent deposition of ore along the course of the dike.

In Fig. 2 and 3 the Bachelor dike is illustrated. Fig. 2 exhibits the relation of the vein to the dike. *A B* is quartz carrying streaks of galena and gray



Section of American-Nettie Orebodies.
After J. D. Irving, U. S. Geological Survey.

copper (tetrahedrite). There is also some blende present. Inclusions of country (sandstone) give the vein a mottled look along its outer edge, between *D* and *E*. The clastic dike *B C* contains several large pieces of shale, and a few signs of ore. The fractures alongside the dike at *X* appear as dark threads of sulphides. In Fig. 3, taken at the east breast of the main drift in the adjoining Khedive mine, the clastic material is 17 inches wide, and exhibits one of those vein-like branches or off-shoots that are not uncommon. In this regard the clastic material behaves just like a lava. The set-off at the top of the section is

In the Heart of the Mountains

Mt. Potosi

also a common feature. Sympathetic fractures occur in the encasing rock. In this instance the vein had merged into the dike and could only be seen vaguely in the form of patches of ore within the body of the dike.

DIKE OF GILSONITE.
After G. H. Eldridge, U. S. Geological Survey.

The whole occurrence is one of great interest. If these clastic dikes are studied with reference to true lava dikes on the one hand and veins of asphaltum or gilsonite on the other hand, it should be possible to arrive at a clearer idea concerning the manner in which rocks undergo the fracturing that precedes ore deposition.

Chapter 3

ACROSS THE RANGE TO TELLURIDE—MOUNTAIN ROADS—THE CAMP BIRD MILL—TREATMENT OF THE ORE—THE LOCAL GEOLOGY—ELECTRICAL POWER.

THE next day, September 6, our cavalcade clattered up the main street of Ouray on our way to Telluride over the Mt. Sneffels range. Cloudless weather, not unusual after the rains of late August, made the ride up Canyon creek to the Camp Bird mill a stimulating pleasure. Much of this road is cut out of the solid rock, in many respects it is a fine example of mountain engineering, and it is kept in good order because it serves as the avenue of traffic for two of the largest mines in Colorado—the Revenue and the Camp Bird. This part of Colorado owes much to an energetic little man who began by being an Indian interpreter, became a road-builder, and finally developed into a successful railroad organizer. Otto Mears is called the Pathfinder of the San Juan; he has left a monument as enduring as Thorwaldsen's lion of Lucerne, which lies sculptured in the rock above the Swiss lake; and much more useful, for the roads that Otto Mears built into the sides of the cliffs overlooking the Uncompahgre and its tribu-

taries have contributed in a large degree to the successful development of some of the best mines in North America.

Mountain roads for heavy traffic should have a grade not to exceed 12 per cent and a width of about 15 feet. On the typical American high-road of to-day the cost of freighting by wagon averages 25 cents per ton per mile;* this rate is always exceeded when the grade is above 12 per cent; in the mountains the rate is often ten times as much, because the loads pulled up the weary zig-zags are small compared to the horse-power employed. Thus, with four animals, averaging 1,250 pounds apiece, a load of 6,000 pounds, distributed between the wagon and its contents, can be handled along an average mountain road at the rate of 1½ miles per hour. When the gradient exceeds 12 per cent it is more economical to pack, that is, to transport material by loading it upon mules or burros. The average cost of this method of transport is from 75 cents to $1 per ton-mile when there is no return load.

We overtook a train of burros with a miscellaneous freight of planks, groceries, and boxes of dynamite destined for a small mine on Mt. Potosi; these, with bulky packages that hid their ears and left only a view of active extremities, looked at a distance for all the world like a migrating colony of Brobdingnagian ants.

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*Mr. James W. Abbott tells me that on European roads the cost ranges from 6 to 13c. per ton-mile, with an average of about 10 cents.

Advancing carefully along the *inside* of the road, the outer parapet of which stood sheer over a precipitous cliff, we hurried our horses past the burro train and soon covered the six miles between Ouray and the Camp Bird mill, where Mr. W. J. Cox, the manager, gave us every facility for inspection. The mill contains 60 stamps, weighing 850 pounds, with a drop of 6 to 8 inches, made 100 times per minute, and a resulting crushing capacity of 180 to 190 tons per day. The pulp passes through cloth screens of 26 mesh and No. 29 wire. It is then discharged upon silver-plated copper tables, which are the full width of the mortar, 54 inches, and have a length of 16 feet. The pulp then proceeds through classifiers, which distribute it among the concentrators, namely, Wilfley tables and Frue vanners. The coarse material goes to vanners that have corrugated belts, the finer pulp goes to the plain belted vanners, and the slime passes on to the Wilfley tables. Experiments were being made in the use of a 5-ft. Huntington mill for re-grinding the coarser sand. This is likely to prove suggestive. The tailing is delivered to the cyanide plant, and is pumped into vats having a capacity of 275 tons apiece, where it undergoes solution for nine days. Tests were being made by Mr. Godfrey Doveton, who had charge of the cyanidation, with a view to determining whether the Johnson filter-press cannot be advantageously employed in the treatment of the slime that overflows from the vats; at present the press is only used in connection with the precipitate from the zinc-

boxes. In Western Australia the large filter-presses have a capacity up to six tons apiece, with a tendency to increase. They were found to expedite the treatment of slime and to economize water. All experiments made in this direction should be useful because they point to a great economy of time and labor.

The Camp Bird ore is one of the most docile. The total extraction of gold is fully, sometimes more than, 90 per cent of the assay-returns from the crude ore. The latter carried about two ounces of gold per ton at the time of our visit; the concentrate represents about 10 per cent in weight and 20 per cent of the value of the original ore, it contains 9 to 12% lead, 12 to 15% zinc, 14 to 16% iron, and 20 to 22% silica (as quartz). It also carries from 2½ to 4 oz. gold and from 11 to 15 oz. silver per ton. This product is sacked and sent on mule-back to Ouray, the charge for transport being $2.50 per ton, for the six miles of down grade. Coal is brought up as return freight at a cost of $4 per ton. The concentrate is then sent over the range by way of the Marshall Pass, to the Denver smelters, 388 miles distant, at a cost for transport, of $7.50 per ton and a charge, for treatment, of $7 to $8 per ton. The bullion, resulting from amalgamation and cyanidation, is sent under escort every day to Ouray, whence it is forwarded through an express company to the mint at Denver.[10]

[10] Since the date referred to, an excellent account of the Camp Bird mill and mine has been prepared by Messrs. Purington, Doveton, and Woods. See *Transactions* American Institute of Mining Engineers, 1902.

After partaking of Mr. Cox's hospitality we mounted again and began the ascent to the Camp Bird mine in Imogene basin. As we surmounted the first rise we found ourselves in a wide amphitheatre of serrated ridges with a broad gap in the direction whence we had come. Looking backward down Canyon creek, one could not fail to observe the fact of a succession of geological formations, on account of the variations in the color of the rocks. The road from Ouray first cuts through a gray ridge of Silurian limestone, then passes over reddish beds of Upper Carboniferous lime and shale, which, in turn, are unconformably overlain by the nearly horizontal beds of a Tertiary conglomerate that has a wide extent throughout the adjoining mining district of Telluride. This conglomerate, known as the Telluride formation, has a particular interest because it lies at the base of a great series of fragmental volcanic rocks (chiefly andesite-breccia) and lava-flows that enclose the majority of the important mines of the region. This is called the San Juan formation. The road intersects the base of the series a short distance below the Camp Bird mill at about 9,100 feet above sea-level, as is shown by the accompanying photograph, where *A B* marks the line of separation between the two formations (the San Juan and the Telluride). Our trail continued to pass over successive layers of the breccia and its intercalated flows of lava until we reached the summit of the range, at 13,800 feet. When a mine is situated in this country of andesitic breccia

Hauling Concentrate from the Camp Bird Mill

Mt Potosi in the Background

The Revenue Mills, near Ouray

The Crest of the Range and the Upper Workings of the Virginius Mine

the distance separating the deepest workings from the sedimentary rocks at the base of the San Juan formation becomes a matter of practical importance, because experience warrants the expectation that an impoverishment will be encountered when the vein passes out of the volcanic series. The Camp Bird lower adit, for example, is about 2,100 feet above the

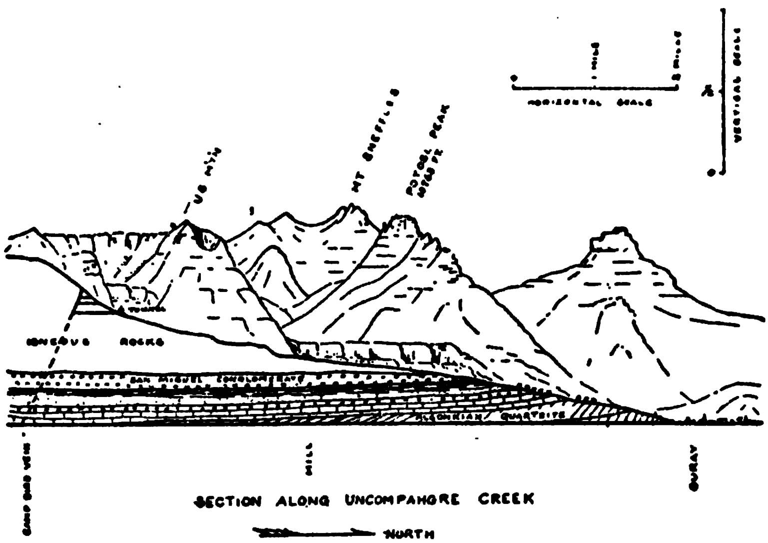


FIG. 5.

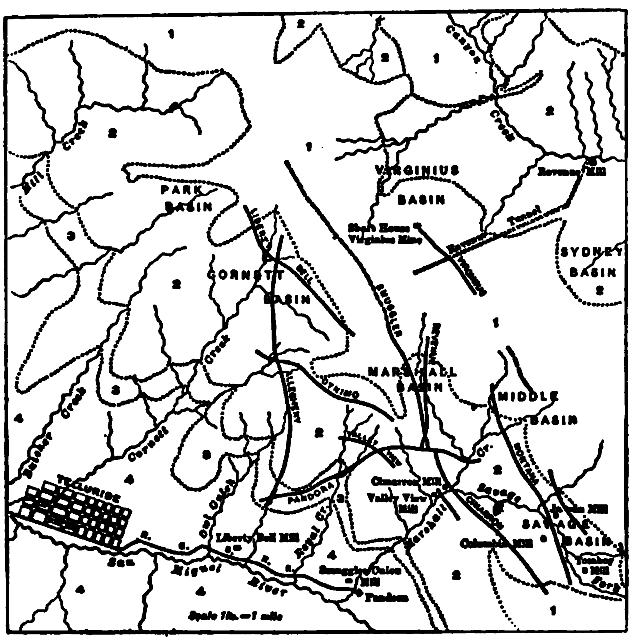
Telluride formation, so that there is plenty of room for further downward development. A generalized section of the geology and topography is given in the accompanying sketch, which I have borrowed from Mr. H. A. Titcomb's article in the Columbia School of Mines Quarterly, of November, 1902. In this sketch the name 'San Miguel conglomerate' appears,

for it was the term originally given by Whitman Cross to the 'Telluride formation.' The old name was surrendered because of prior use by Texas geologists. So the name of the town replaced that of the county.

The Virginius, a neighboring mine, has an adit —the Revenue tunnel—which strikes the vein at a point 2,400 feet below the outcrop and 10,800 feet above sea-level. The conglomerate is supposed to be about 1,000 feet deeper. A shaft has proved the vein for 900 feet below the adit, so that the total exploration on the vein extends for a vertical height of 3,300 feet, which is the deepest development attained by any mine in Colorado. The Virginius vein is remarkable in other respects also. It has been worked for more than twenty years. For the first 400 feet in depth the vein was stoped continuously, although its width only ranged between a finger and a hand's breadth. The ore was chiefly gray copper (argentiferous fahlerz) and averaged 400 to 600 ounces of silver per ton. At about 1,200 feet from the surface, the shaft, which followed the vein, entered a poor zone that extended for 300 feet further. At the level of the Revenue adit[11] another poor zone, about 150 feet thick, was encountered. The new vertical shaft, sunk from the adit, has found good ore, 30 inches wide, at 550 feet. The Virginius, by the way,

[11] It is a pity that the word 'tunnel' is so often misapplied. In the above case, and ordinarily in mining, the word 'adit' should be used. A tunnel is a gallery or working that reaches *from* daylight *to* daylight, like a railroad tunnel. A main cross-cut or level that connects a mine with daylight is an 'adit.'

has a large electrical equipment, which operates both mine and mill. The motor cars used for underground traction are remarkable in taking the high pressure of 800 to 900 volts from a bare wire placed about the height of a man's head. The power is generated from a succession of Pelton wheels, which use the water of Canyon creek. They present an interesting feature in the fact that the nozzles are worn out in ten days by the action of sand at high velocity, which is the consequence of using a stream charged with tailing from a mill.



1. Rhyolite and Andesite. 2. San Juan Breccia.
3. Telluride Conglomerate. 4. Shale and Sandstone.

MAP OF TELLURIDE DISTRICT, COLORADO.
After U. S. Geological Survey.

Chapter 4

THE CAMP BIRD MINE—STORY OF ITS DISCOVERY BY THOMAS F. WALSH—ON THE TOP OF THE RANGE.

PON arrival at the Camp Bird, the superintendent, Mr. William Beaton, piloted our party through a portion of the workings. Both F. L. Ransome and C. W. Purington have recently described this lode in detail.[13] A production, up to date, of about $7,500,000 places the Camp Bird among the great mines of Colorado. It is also interesting as having been until lately the property of the man who opened it up, namely, Thomas F. Walsh.

The history of the discovery of this celebrated mine is curious. The only outcrop of the vein for several thousand feet is in a small gully right at the head of Imogene basin. A claim was located on this outcrop in 1877, but nothing further was done because no ore of any value was exposed at this point. William Weston and George Barber, who were the owners, made a proposal to H. W. Reed and Caleb Reed that if they would run a cross-cut into the mountain, so as to cut the vein at about a depth

[13] *Bulletin* No. 182. United States Geological Survey, pp. 89-90 and 200-204, and *Transactions* American Institute of Mining Engineers, May, 1902.

of 150 feet, they could have the option of locating a new claim on whichever side of the cross-cut they chose. The cross-cut was run, and in due course intersected the vein. The Reed brothers drove 50 feet to the west and took up a claim on that side. This was then patented under the name of the Una claim. On the eastern side the Gertrude claim was pegged out by Weston and Barber, who, later on, sold it to the Allied Mines Company. This was in 1878. Subsequently the company extended a drift for 40 feet into the Gertrude ground, but found no ore of any value; later still, another 10 feet was driven, so as to make the distance 50 feet, and thus qualify for patent. This was in 1884. The ore in the last 10 feet was *not* assayed because the work was only done to fulfill legal requirements and the first 40 feet of the drift had yielded no pay-ore. But as a matter of fact the drift had, in the last two or three feet, broken into rich ore; it remained there undetected until 1896, when Walsh broke some samples and had them assayed, thereby taking the decisive step toward becoming a millionaire. Moral: Never fail to test the ore of a drift that is penetrating into new ground, and never assume that ore is poor because it *looks* like ore you know to be poor.

The rest of the story is well known. Walsh was an experienced miner who had met with some success both at Leadville and Rico. In 1896 he was manager of the smelter erected at Silverton for the treatment of the ores sent down from Red Mountain by the

Yankee Girl and Guston mines. Walsh had, in 1894, organized the company that put up this plant. In the search for silicious ores he investigated the mines of the surrounding country, not only those in operation, but also the abandoned prospects. He acquired the Hidden Treasure mine, in Imogene basin; this was a low-grade silver-lead property, which has never done much. In July, 1896, he went to see how work was going on at the Hidden Treasure, and incidentally he noticed some pieces of pink spar amid the rock-fragments scattered at the foot of the cliffs that form the upper limits of Imogene basin. This pink spar he took to be fluorite, and because it reminded him of Cripple Creek, where also he had mined with some success, he made a mental note of the occurrence. In the following September he revisited the locality and climbed up into the old Gertrude adit, from which he inferred the pink spar to have come. It was rhodochrosite; but no matter. It led him to take samples at the breast of the east drift. They were sent at once to Ouray to be assayed. The returns gave several ounces of gold per ton. More samples were taken and sent to Leadville for assay. These results were confirmatory, so he went to work quietly and began the steady consolidation of the adjoining property. Mr. Walsh's success was the reward following many years of most energetic search, a search backed by unusual experience in mining and extending over a large area that contained a great number of deserted old workings

Mt. Wilson and the Valley of the San Miguel

SAVAGE BASIN

A Upper Tomboy Workings B Old Tomboy Mill C New Tomboy Mill D Japan Mine

likely to prove remunerative under new economic conditions.

The main level of the Camp Bird is now over a mile in length, so that when we emerged from underground it became necessary to make haste in order to cross the range before dark. Ouray is 7,806 feet above sea-level, the No. 2 level of the Camp Bird is at 11,510 feet, and the place where the trail crosses the divide is at an altitude of about 13,800 feet. The trail is a good one in summer, so that we did not require to lead our horses save in the steepest portions of the rise and in the abrupt descent on the other side.

When we attained the summit a halt was called while we surveyed the splendid panorama of mountains that lay outspread on either hand. Looking back over the course we had traveled we could see the shadows hastening to cover the valley of Canyon creek and the sheltered corner among the hills where Ouray lay concealed; in the far northeast the dark mass of the Uncompahgre plateau loomed purple in the fading light. Looking the other way, the grim desolation of time-worn summits and crumbling crags reached down into the gloomy gorge of the San Miguel, which suddenly broadened into the sunlit valley of Telluride, checkered with cultivation and bright with the gleam of blue water. Beyond were green foothills, out of which arose the sculptured mass of Mt. Wilson, silhouetted against the setting sun, and further still, northwestward, rim upon rim of far-off hills fading into the bourne of distant Utah.

Chapter 5

MILLS AND TRAMWAYS OF TELLURIDE—OPERATIONS AT A HIGH ALTITUDE—SNOWSLIDES AND THEIR TRAGEDIES.

HE descent to Telluride was tedious, for it meant leading our horses most of the way; and some horses are particularly slow to be led, however willing to be ridden; besides, the drop from the top of the range to the valley is just five thousand feet in the course of five miles. All the way down we passed mines and mills; of the latter, the new Tomboy mill in Savage basin loomed conspicuous through the dusk.

At first sight it seems curious to build a large mill at an altitude of nearly 12,000 feet, instead of choosing a site in the valley and transporting the product of the mine over an aërial tramway. This is a much-mooted question. As a rule the valley site is preferable, by reason of the availability of a water supply, the greater cheapness of fuel for power and heating purposes, the nearness to a base of supplies, the facility that the tramway itself gives for transmitting materials up to the mine, the more kindly conditions of living for workmen, etc. If water can be secured

the erection of a mill close to the mine itself will save the cost of a tramway, that is, an amount ranging, say, from $20,000 to $50,000; but the water-supply of the high altitudes is so closely dependent upon melting snows as to be uncertain, unless a reservoir or natural lake affords a chance for storage. Of course, if the mill is at the mine, the concentrate has to meet the cost of carriage to the valley and this can be, in part, set off as against the expense of tramming the ore itself to the mill, if situated at a lower level. The Tomboy pays $2.75 per ton for packing concentrate from the mill to the head of the valley, at Pandora, and as the ore yields from 8 to 12 per cent of concentrate this cost represents about 25 cents per ton of crude ore. The item of fuel for motive power is eliminated by the electrical transmission of power. Blacksmith coal is carried by the pack-train to the Tomboy at a cost of $8 per ton, an amount one-half of which represents the expense of transport. The mill and other buildings are heated by steam; in some cases by low-pressure boilers, in others by high-pressure boilers with reducing valves. In summer 40 tons of coal are consumed per month; in winter, 200 tons are consumed per month. Coal costs an average of $10 per ton, delivered at the mine. Water for milling purposes is obtained from Lake Ptarmigan by a pipeline one and three-quarter miles long.[18] The lake is

[18] The line starts with a 5-in. pipe, which is reduced to 4 inches at the summit; from the summit to the mill it is reduced, gradually, to 2½ inches. For these and other data I am indebted to Mr. John Herron, the manager of the Tomboy mine.

just over the range and only 350 feet below the crest, so that light pumps serve the purpose. These are operated by electricity, which is bought from a large power company in the valley, at the rate of $80 per horse-power per annum. The Smuggler-Union mine, which has its own generating plant, pays only $35 to $40 per h. p. per annum, but as against this, of course, are offset the interest and redemption of the capital used for an expensive installation.

On the whole, therefore, it may be said that the comparison of conditions affecting the operation of a mill in the valley and that of a mill at the mine is without decisive result and depends entirely upon local factors. One of these is the ability to secure a good mill-site at a reasonable price. Another possible factor is the snowslide. To a stranger the interruption and damage from this source would seem to present a very serious obstacle to the use of a tramway. It does, but to the same extent it affects all the operations in a precipitous snowy mountain region. Last spring[14] the Smuggler-Union tramway was stopped for several weeks in consequence of the damage done by a slide, and during the same season the Liberty Bell mine-buildings were swept away, so that the mill was idle for four months. In the latter case 18 lives were lost, and the majority of these belonged to rescue parties that set out to the aid of those who were caught by the first slide. Successive rushes of snow entombed the rescuers.

[14] That is, in 1902.

The snowslides that bring devastation to the mines of southwestern Colorado represent a recurrent peril, for they are at work each spring with variable intensity. Of all evidences of Nature's power there is none so feared by the miner as this, 'the thunderbolt of snow.' After the winter snows have fallen and by successive thaws and frosts have become packed, there comes, during the period marking the end of winter, a heavy snowfall, which, settling and accumulating upon the hardened surface of the earlier precipitation, is ready to be launched down the steep slopes of the mountains with all the suddenness of a thunderbolt and all the confusing terrors of a whirlwind. A slight movement may disturb the uneasy equilibrium; even a mountaineer's footfall may cause a huge mass of snow to become detached. In southwestern Colorado, where the mountain slopes are steep and but poorly protected by forests, there are more people killed each year from snowslides than in Switzerland, although the man of leisure who risks his life climbing the Swiss heights usually receives more mention in the daily press than the miners and other humble individuals that lose their lives in the San Juan while going to and from their labor.

The destructiveness of a snowslide must be seen to be appreciated; buildings and tramways are as toys before its fierce oncoming and men in the path of its descent are as straws in a whirlwind. In fact, much of the damage is due to the vacuum caused by

the rapid motion of a mass of snow and the cyclonic disturbance that follows in its wake. I have often watched a snowslide descending a neighboring ravine, when myself out of all danger. The thunder of its tempestuous descent first attracts attention, and then one sees the mass of snow gathering underlying rocks, uprooting trees, amid a quickly gathering mist of snow particles drawn fiercely by the whirlwind in the rear. The rushing mass will not stop at the bottom of the slope, but its momentum will carry it some distance up the opposite declivity, while all the forest trembles and the air is darkened with a snow mist.

Ouray, Silverton, Telluride, and Creede—all in the region formerly known as 'the silvery San Juan,' but now identified chiefly with profitable gold mining—are localities where snowslides are of yearly occurrence. One of the worst seasons in this regard was the spring of 1884, when a series of slides came down into the cañon of the Animas, below Silverton, so as to blockade the Rio Grande railroad to Durango. In 90 days only two provision trains managed to get through; for this was in the days before the rotary plough. Nowadays such prolonged interruption to traffic is unknown. In March, 1902, as already related, 18 men were killed at the Liberty Bell mine, above Telluride; the mill buildings were swept away and the tramway was severely injured. Since then the management of the Liberty Bell has built a V-shaped crib-work of solid timbers, filled with rock, in the path of the slide that did this damage. Their

THE LIBERTY BELL MINE
The Snowslide Swept Down from the Mountain and over the Covered Car-track

The Bullion Adit, of the Smuggler-Union Mine

foresight was rewarded during the spring of 1906, for the snow broke away as before, but the slide was divided by this obstacle and did comparatively little harm. The slide that smashed the Camp Bird mill is called the United States, because it annually descends in a ravine past an old mine of that name. Snowslides usually follow a line of destruction marked out by them in previous years; this path is indicated by the removal of trees, forming a lane through the forest; it is also marked by the accumulation of débris, and by piles of snow that survive successive summers. The United States slide comes down a steep slope, it crosses the road to the mine, and descends into the valley traversed by the tramway, the towers of which are protected by a timber cribbing. The Camp Bird mill is a little over half a mile away and had never been visited by this slide. Above the mill are steep hillsides covered with pine, which were considered to indicate immunity from such danger. In 1906 the mass of snow and the velocity of it were such as to carry the slide down the valley and over the edge of the hollow in which the mill stands, so that the vast body of snow dashed down the precipice and broke the mill-building like an egg-shell. It was a similar supposed immunity from danger that caused the Liberty Bell catastrophe; for, of course, the buildings were erected at a spot confidently believed to be beyond the range of any slide.

Chapter 6

DESTRUCTION OF THE CAMP BIRD MILL—THE ASSASSINATION OF ARTHUR COLLINS—LABOR RIOTS.

ANYON CREEK is illustrated on the page opposite as it appears in summer looking from the Camp Bird mill toward Ouray; the photograph was taken soon after our visit and before the events of March 17, 1906. On that date a snowslide, followed by a fire in the ruins, completely destroyed the big mill shown in the right foreground of the illustration just mentioned. The next three pictures exhibit a scene of desolate grandeur; they are reproduced from unusually fine photographs given to the author by Mr. B. Kehoe. In the first, the track of the snowslide is seen through the smoke and steam ascending from the burning ruins; the nearly horizontal layers of andesite breccia form tiers rendered distinct by benches of snow and the serried ranks of pine. In the distance a tall peak, rising from snowfields, pierces a troubled sky. It is a scene of impressive desolation and amid such a theatre of natural destructiveness the surviving mill-buildings look insignificant indeed. In the second there is a nearer

LOOKING DOWN CANYON CREEK
The Camp Bird Mill Buildings in the Foreground

Camp Bird Mill Burning

view of the burning mill; the heaped snow to the right represents the end of the slide; the towers of the tramway are silhouetted against the sunlit surface; a few men and horses can be discerned indistinctly. In the third illustration the brilliant sunshine throws strong shadows from the pines, so that the left hillslope suggests a reflection in water; the fire in the ruins has almost burnt itself out, the steam does not obscure the view and the great peaks of the range at the head of Imogene basin are in plain sight. Nature, having destroyed, is smiling. In this scene no human beings are discernible; man's insignificance is emphasized.

The snowslide that demolished the Camp Bird mill was typical of this form of natural destructiveness. The facts are these: For a number of days the snow had fallen, so that a thick covering of new snow lay on the smooth frozen surface of the winter. Starting high on Mt. Hayden, the slide first upset thirteen towers of the tramway and then, leaping over a high cliff, it wrecked several warehouses and coalsheds before it struck the mill itself. Before coming to rest, it crushed the lower story of a bunk-house, devoted to a reading room, endangering the lives of seven men, who were rescued comparatively unhurt. As earlier slides on the same day had broken the wires that transmitted electric power, the mill happened to be idle and only three men were in it. One was unhurt, though entangled in the wreckage; a

second was dug out from under three feet of snow and timbers, also only slightly bruised; the third was killed. The avalanche made no noise save when the timbers of the mill cracked, but the air was quickly laden with a mist of snow. The particular slide that did the damage was known, that is, its path in previous springs was marked by a lane in the forest above the mill, but it had never been known to run so far or to be so violent; otherwise, of course, a different mill-site would have been selected.

All of this happened on a Saturday evening; on Tuesday morning a fire was detected in the upper part of the boiler-house and this spread fast, so that all that was left of the mill was soon consumed. As the storage-tanks had been destroyed, there was no chance to fight the fire. According to Mr. Stephen L. Goodale, the odor of quicksilver was apparent for several days after the event. "The amalgam on the battery plates was pretty thoroughly parted and the 'quick' driven off, leaving a gold plate on the copper. In the clean-up pans most of the amalgam had been parted, and the gold was left as a well-retorted dirty sponge; but a little amalgam and quicksilver were also left." *

There is only one way to avoid this danger; for buildings, not to erect them at the foot of snowclad slopes; and for men, not to go abroad on the mountains just after a fresh snowfall, especially when it

* *Mining and Scientific Press*, April 14, 1906.

comes on top of a hardened surface. But even the greatest care is insufficient, as we have seen, and so long as the mountains raise their proud heads to heaven they will occasionally shed their white mantles of snow, imperiling those who invade them in quest of gold.

The stretch of country covered by Marshall and Savage basins, and thence to the valley at Pandora, has seen many a snowslide. A long tale of woeful fatalities and romantic heroism could be told concerning these three or four miles of mountain land. In the cemetery at Telluride there are many large graves enclosing the remains of groups of unfortunate miners who were swept into eternity by 'the awful avalanche.' Their resting places are unadorned by showy tombstone or grandiose epitaph, but close-by a new white marble monument attracts the spectator to read the inscription upon its face. It tells a startling story to those who can read between the lines. In July, 1901, the management of the Smuggler Union mine introduced the system of working by contract, a system that results in paying a workman according to his work, and which, therefore, is directly opposed to the underlying principle of unionism, which demands an equal wage for the idle and the energetic, the capable and the incapable. There was a strike, the members of the union, for the most part, refused to work, while a large proportion of experienced miners accepted the contract system and remained at the mine. On the 3rd of July, the eve

of the Declaration of Independence, a body of strikers attacked the mine, shot indiscriminately into the bunkhouses, offices, and other buildings, succeeding in killing eight non-union men and in driving the remainder over the range. In this cowardly assault one striker was shot. It is his tombstone that so conspicuously adorns the Telluride cemetery; upon it there is this inscription: "Erected by the 16-to-1 Miners' Union in memory of (then follows the man's name). Born in Koojoki Wora, Finland. Died at Smuggler, Colo., July 3, 1901, aged 27 years." Then follow these noble lines of Longfellow:

> "In the world's broad field of battle,
> In the bivouac of life,
> Be not like dumb driven cattle—
> Be a hero in the strife."

This—this is the prostitution of poetry! Remember, too, that no one has ever been punished for the murder of the eight miners killed on that same day, while the one murderer, killed in the act, is commemorated in marble and in poem!

This intolerable outrage emphasizes the conditions of affairs in the Telluride district. There has been a manly effort made by three or four of the mine managers to protect the rights of property and good citizenship, but it has been handicapped by the interference of political considerations. Arthur L. Collins, the manager of the Smuggler Union mine, told me of the receipt by him, from the secretary of the union, of a list of 'scabs,' namely, men who refused to accept the edicts of the union—16-to-1 union, if

Destruction of the Camp Bird Mill by Snowslide and Fire

After the Fire at the Camp Bird Mill

you please! This list was interesting because the names upon it could be pronounced!—that is, they belonged to men of American and English descent, as against the bulk of the miners in the district, who are Austrians, Italians, Slavs, etc. Mr. Collins inserted a paid advertisement in each of the local papers promising work at the mines under his charge to any man on that list.

The above lines had just been written, on November 19, 1902, when the news of the assassination of Arthur Collins shocked the whole profession of which he was so honorable a member. I have elsewhere[18] expressed my feeling concerning this tragedy. It is a bitter price to pay for frontier lawlessness and that political expediency which holds the law bound in its slimy coils.

[18] The editorial on the 'Tragedy at Telluride' in the *Engineering and Mining Journal* of November 29, 1902.

Chapter 7

THE SMUGGLER-UNION MINE — STRUCTURE OF THE LODE — GEOLOGICAL CONDITIONS — VARIETY OF MINERALS.

HE mine that was the scene of these unhappy doings is one of the largest in Colorado; it was discovered in 1875, when one of the claims, the Sheridan, was first located. A stray occurrence of the mineral sylvanite, the telluride of gold and silver, was the cause of the naming of the mining camp. The lode proved remarkably persistent in richness through the Mendota, Sheridan, Smuggler, and Union claims, and beyond them into other mines; it has been traced for over four miles on its strike and it has been continuously stoped along one portion for a length of 5,000 feet. The Smuggler lode has yielded altogether about $12,000,000. It cuts through the crest of the range at 13,200 feet, where it is encased in rhyolite; at 12,450 feet it passes into a sheet of augite-andesite, which is 550 feet thick, and below this it goes through the great series of andesitic breccias that reach down to the Telluride formation, at an altitude of 10,000 feet. The variation in geological environment has not been without

The Smuggler-Union Mills at Pandora

Continuation of Preceding Photograph

In the House at the Left of This Illustration and at the Right of the Upper One, Arthur L. Collins Was Assassinated

The Smuggler-Union Mill at Pandora

its effect upon the character of the vein. Mr. Collins informed me that the payable part of the vein reaches up to the rhyolite cap, the limit of productiveness coinciding to a remarkable degree with the base of the rhyolite, where the vein is pinched, becoming merely a persistent parting, easily discernible even at a distance on account of the discoloration of the encasing rock. In the rhyolite, the vein is accompanied by a little mud or selvage and some silver ore, in patches,[16] but no cellular quartz such as can be seen lower down. This bit of evidence does not favor the idea of a secondary enrichment of the lower orebodies by means of the removal of the precious metals in the uppermost portions of the vein. In the augite-andesite the bonanza orebodies occur, the richest masses of silver ore coinciding roughly in their distribution with certain harder, almost horizontal, layers of this andesite. Similarly, in the underlying breccia, which is fine-grained, the pinches in the vein occur along nearly level lines coinciding with the bedding-planes of the country. Good ore makes in zones, but oxidation reaches downward irregularly, and does not coincide with enrichment.

The Smuggler vein, as the drawings will show, is notably banded; the hanging wall is usually well defined and carries a casing, immediately underneath which a persistent quartz leader is generally to be

[16] Mr. John B. Farish has since informed me that in the adjoining ground, of the Humboldt mine, he found that these patches of ore in the rhyolite indicated orebodies in the underlying andesite.

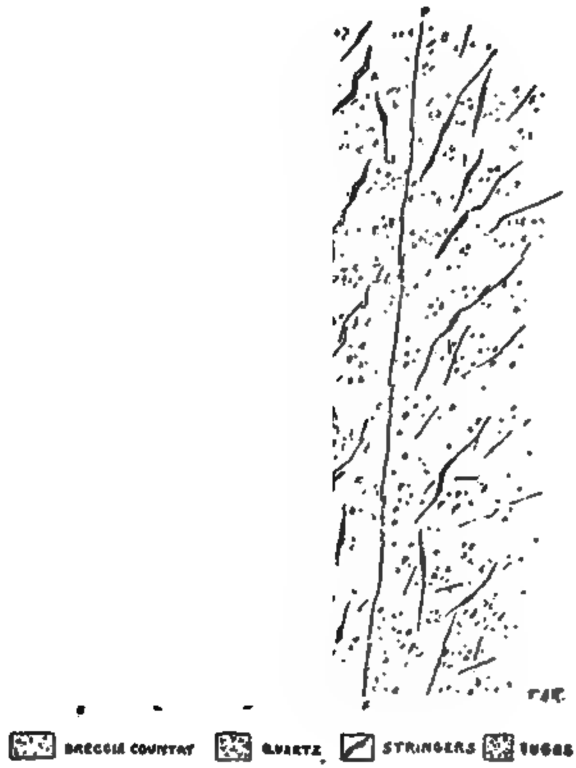


FIG. 6.

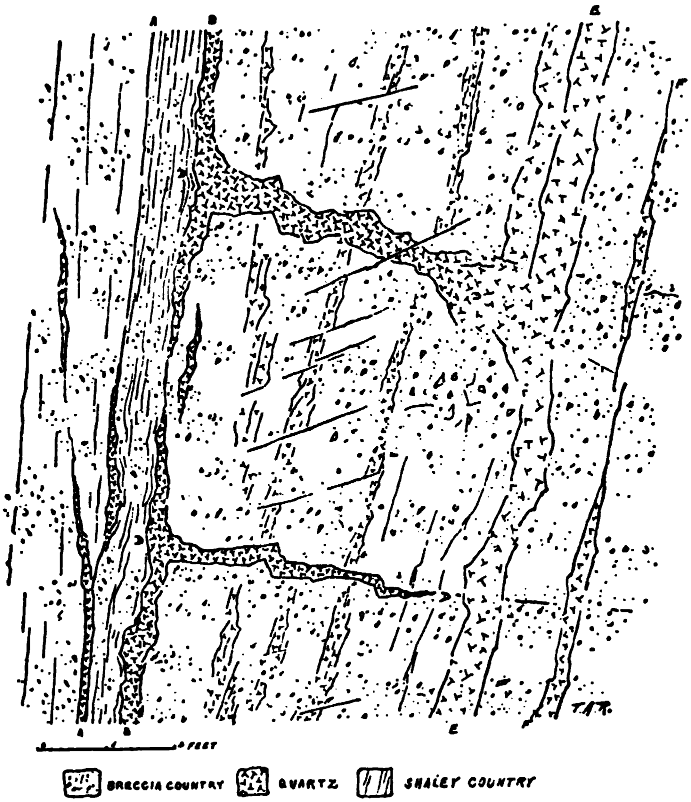


FIG. 7.

seen. This leader is the first part of the vein to show oxidation. The footwall is 'frozen' with quartz stringers, which merge into the country. The general structure of the vein suggests multiple fracturing with but slight actual displacement, and a shattering of the rock without much actual crushing. Vugs, or cavities lined with crystals, are frequent; they are due to crustification, or crystalline growth, around the sides of spaces separating pieces of broken rock.

The accompanying drawings were made underground during a visit in 1901; Fig. 6 represents the back of a stope at the ninth level. On the hanging there is a quartz seam, *A A*. This is usually the rich streak; if any free gold is to be found in the lode, it will be found there. The quartz is white and rather massive, with crystalline vugs. The next band, *B B*, is a strip of hard country, included in the vein; the part *E* to *D* is also breccia, with some quartz; the foot-wall country, *D F*, is full of quartz stringers that drop into the vein; the outer country contains vugs and some quartz. On the hanging there is a soft shaly band, about three feet wide, which is used by the miners as a 'shooting course,' that is, it is recognized as an easy line of fracture and separation between the ore and the rock.

Fig. 7, obtained in a neighboring stope, suggests the arrangement of ore in relation to the bedding of the breccia. The hanging-wall leader is represented by the stringer *B B*. *A B* is a casing of soft shaly country corresponding to the 'shooting course,' as

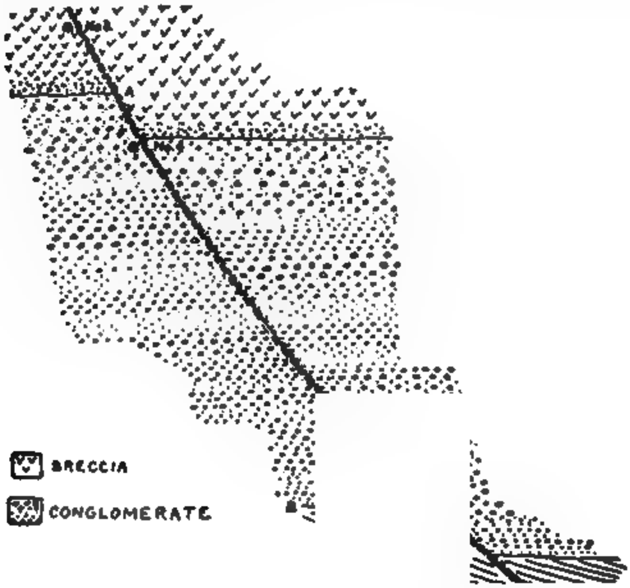
described in connection with Fig. 6. *D D* are seams of white quartz carrying iron-stained vugs. *E E* is a quartzose band. The included country in the middle of the vein, from *B* to *E*, is mottled by brecciation and does not contain as much quartz as is usual. The foot-wall is hard.

The lode yields a wonderful array of fine crystals of quartz, siderite, calcite, argentite, rhodochrosite, gold, and silver. The transparency of most of these, especially the quartz and the siderite, suggests an extremely slow process of crystallization. Siderite, the carbonate of iron, occurs in handsome yellow crystals encrusting both quartz and calcite. Calcite was the last mineral to be precipitated, and it is found lying upon the quartz that lines the geodes or vugs. Rhodonite, the silicate of manganese, occurs in irregular bands, usually on the foot-wall or else in the main body of the pay-ore. Rhodochrosite, the carbonate of manganese, is occasionally seen in rose-red crystals. Gold is found in crystalline aggregates forming specimens of great beauty. Wire gold also occurs. Both the wire and the crystalline gold have the composition of the true alloy, Au Ag.[17] In the upper workings, the native gold is purer.

While the lodes of the vicinity, as a rule, have the general structure of sheeted bands of country rather than that of large fault-fractures, it is noteworthy that several of the poorer veins follow pronounced lines

[17] A fact determined by the late Arthur L. Collins, who gave me many of the data contained in this description of the Smuggler-Union lode.

of faulting. I measured the vertical dislocations that coincide with the Contention and the Allegheny veins; in the first case the displacement is 58 feet and in the second it is 21 feet. The Pandora faults the



CROSS-SECTION OF THE CONTENTION LODE.

Smuggler about 50 feet.[18] The Virginius vein is faulted twenty feet by a cross-vein.[19] In these cases it is the poor vein that follows the fault.

[18] John A. Porter. 'The Smuggler-Union Mines, Telluride, Colorado.' *Transactions* American Institute of Mining Engineers. Vol. XXVI, p. 452.

[19] C. W. Purington. 'Preliminary Report on the Mining Industries of the Telluride Quadrangle, Colorado,' U. S. Geological Survey, p. 837.

Chapter 8

THE CONTENTION MINE—AN AERIAL VOYAGE—GOOD MINE MANAGEMENT.

WE spent a couple of days at Telluride, visiting the mines in the vicinity. Two of our party went up to the Contention mine, and avoided a long ride over road and trail by getting into one of the buckets of the tramway, which makes a bee-line up the mountain side. The aërial voyage was made speedily and safely, if not very comfortably. In winter the managers of many of the properties find it expedient to make their trips to the mines over the tramway, and in spring, when the deadly snowslide may launch itself down the mountain at any time, it is much safer to travel in the air, not because the tram is always immune from this peril, but because of the shorter time to which one is exposed to danger in making the journey in a bucket, as compared to floundering painfully on horseback or toiling patiently uphill on snowshoes.

The Contention is an interesting lode because it is productive of gold ore in a Tertiary conglomerate, not in the form of a bed of conglomerate impreg-

nated with gold,[30] but a nearly vertical vein-fracture cutting through a nearly horizontal formation and passing above this conglomerate into the andesite-breccia series and below the conglomerate into sandstones of the Jurassic. This is an example of the great diversity of geological environment that distinguishes the Telluride district; within a small area productive gold and silver veins have been worked not only in the Tertiary volcanics and the Tertiary conglomerate underneath them, but also in Jurassic limestone (the Sawpit mines) and in Triassic sandstone (the Allegheny). This, however, is a subject too wide for more than incidental reference.

The photograph of the Smuggler-Union tramway illustrates the usefulness of this form of transport for sending supplies of all sorts to the mines at high altitudes. Timbers, lumber, coal, food, and tools are put into the buckets and, when necessary, a couple of buckets are spaced so as to carry the long timbers or pieces of lumber. But besides this constructive engineering, the photograph referred to also affords a natural geological section. On the face of the cliffs overlooking Pandora it is possible to trace several successive geological formations. Thus *A A* represents the base of the series of bedded tuffs and breccias called the San Juan formation; then (down to *C C*) comes the Telluride conglomerate, and under it are the two layers of white sandstone separated by a dark band of limestone, constituting the La Plata

[30] Such as the conglomerate beds of the Witwatersrand, for example.

Smuggler-Union Tramway. A Load of Lumber

Marshall Basin
The Sheridan, Mendota, and Union Mines

formation; still lower, along *B B*, the red grits and sandstones of the Dolores formation can be followed along the face of the cliff. Between the Telluride conglomerate and the underlying succession of sediments there is an unconformity, which can be seen by an observer standing on the trail that ascends the opposite slope.

The big mines of the Telluride district afford examples of good management and the close economy that goes with such management. During the past fiscal year the Tomboy treated 85,726 tons of ore, the average yield of which was $9.98 and the average cost per ton, $5.85. With the help of the new mill, the costs are expected to be brought down to $5.50. The Liberty Bell mine, for the year ending September 30, 1902, despite snowslides and other unforeseen delays, handled 67,439 tons for a yield of $7.15 per ton, at a total working cost of $5.53 per ton; while the Smuggler-Union, on a larger tonnage, has brought the total expenses to just under $4 per ton. In 1902 the average mining costs were $2.90 and milling expenses $0.90 for 92,917 tons. Summer costs were better than those in winter; for instance in April, 1902, the mining cost was $2.81 and the milling $0.74, for 12,979 tons. The figures for mining include expenses up to delivery of ore at the dump.

In referring to good management, it will not be out of place to mention the action of the manager of the Tomboy mine, who, when the old mine had evidently become exhausted, was enterprising enough

to secure options on adjoining ground, at that time giving promise of a good thing. Mr. Herron bought the Argentine for his company and thereby put the Tomboy on its feet again. In his negotiations he was supported by his directors, and the result is the possession of a mine that has made the shares of the company more valuable than they were at the time of its organization. Mr. Herron acted for the directors, the directors acted for the shareholders, and although the transaction was a large one the shareholders were debited only with a bonus of $10,000, which was given by the company to the mine manager in recognition of his services. It is an incident worthy of record and does honor to all concerned. If managers and directors of mining companies always took such a proper view of their duties, the industry of mining would gain thereby.

A Fault-Vein Faulted.

Looking Backward from the Bridal Veil Trail

The Trails to the Smuggler-Union and Other Mines in Marshall Basin Can Be Seen. The Cliffs above Pandora Are in the Light

TELLURIDE AND ITS GEOLOGICAL SECTION

1. The Dolores formation (Triassic)
2 and 6. La Plata sandstone (Jura-Trias)
3 and 10. McElmo formation (Jurassic)
4 and 5. The conglomerate of the Telluride formation (Eocene)
7 and 9. The breccia of the San Juan formation (Eocene)
8. Potosi rhyolite

Between 7 and 8 there come the flows and breccias of the Silverton volcanic series

Chapter 9

ON THE WAY TO SILVERTON — THE BRIDAL VEIL FALLS — FINE GEOLOGICAL SECTION — OPHIR — THE RED MOUNTAINS.

ON the 8th of September we started for Silverton. We took the recurrent zig-zag of the Bridal Veil trail, and in an hour reached the top of the waterfall, whose filmy traceries had originated the name. The beauty of the waterfall is gone, a sacrifice to utilitarian engineering, which has taken the water to supply power to the Smuggler-Union mill. The pipe-line climbs to the place where once the rivulet flung itself into space, and the penstock stands where it paused for breath before its leap into the sunlit ravine. As we halted at the head of the trail, the San Miguel valley lay outspread with panoramic spaciousness.

Nearly horizontal lines of differently colored rocks in ordered succession gave the suggestion of long-continued natural forces building up the superstructure out of which the sculpturing hand of Time had chiseled the great array of mountain peaks that rose against the cloudless skies. Emerson has said somewhere that we ought to respect "the *naturlangsamkeit* which hardens the ruby in a million years, and

works in durations in which Alps and Andes come and go as rainbows." It is restful to contemplate this patient operation of natural forces in contrast to the unresting eagerness of man—a nervous energy nowhere more marked than among the mines and mills which lie under the shadows of these very mountains. Such contemplation should conduce to equanimity. I think it does. The records of the geological societies show that geologists, as a rule, live long.

Above the valley rise the short slopes of red sandstones of the Trias, surmounted by the white line of the La Plata sandstone at the base of the Jurassic, and above this distinct stratum, marked by a medial layer of dark limestone, there succeed the variegated shales and sandstones of the McElmo formation at the top of the Jurassic; these, being fairly soft, have a gentle slope, partly covered by vegetation, and are topped with the gray band of the Dakota sandstone, at the base of the Cretaceous. All these rocks dip down the valley westward, so that the horizontal bedding of the overlying Telluride conglomerate brings out the unconformity distinctly. This Tertiary conglomerate has a dark red color, as seen from a distance, and it belts the base of the steep cliffs above the valley conspicuously. It is about 400 feet thick just below Pandora, and is covered by the vast succession of volcanic ejectamenta, which rise tier upon tier for a height of 3,500 feet, culminating in serrated peaks that soar far above the uppermost limits of vegetation.

In leaving this wonderful geological section it will not be unfitting to suggest that instructors of geology in our schools of mines will find nowhere on the globe a better locality wherein to bring home to the student the relation between geology and mining, nor will they find, with convenience, a district that illustrates so well the working and the results of natural erosion, the operation of which Hutton and Lyell emphasized as fundamental among the processes of nature.

When we resumed our ride, we found ourselves on a trail threading a pine forest. In sheltered spots the wild flowers of summer still lingered, and the trail crossed busy rivulets, whose voice was the only sound disturbing the quiet of regions strangely devoid of life. Emerging from the pines, we found ourselves on the treeless waste above 'timber line,' and followed an easy ascent along the bare rounded slopes at the head of an amphitheatre of ridges. It was a lifeless desolation, bleak and still, until suddenly a series of salutes rang out, to be echoed grandly from peak to peak. These were the blasts from mine-workings which we had not seen; they marked the noon hour. It was time for 'croust' (literally crust), as the Cornish miners call the meal that divides their working time; so we off-saddled beside the first stream and ate our luncheon, while the horses nibbled the scant dry grass. It seemed good to be there under that serenely blue sky and amid an air that made "the world seem young and life an

epic." Those who do not know the exhilaration of these high altitudes have not realized what perfect vitality means.

On resuming the ascent, we were soon amid loose slopes of débris, over which the horses went with no more difficulty than ourselves, although the increased rarity of the air told on them very obviously. The trail was lost, and on choosing the lowest ridge to the south, we found ourselves eventually where we did not expect to be, that is, overlooking the little mining town of Ophir, which I knew to be out of our course to Silverton. We looked from a razorback ridge far down a precipitously steep slope into a distant little green valley; a white road threaded the centre of it, and a cluster of dwellings, like match-boxes, seen so far, marked the settlement of Ophir. This is not Solomon's treasure-house, but as the slanting sunlight touched the clusters of yellow aspen upon the lower slopes of the valley we found reason enough for the name.

Retracing our steps into the basin from which the ridge arose, we crossed to the eastern side, and finding a trail, ascended a crumbling ridge, from which we could see the whole complex of ranges stretching from Red Mountain to Silverton, and far beyond. We were 13,200 feet above sea-level. It did not take long to regain our wind, and shortly the four of us were picking a way down the farther side, winding in and out of those semi-circular basins which are so characteristic of the high country just

Timber-Line. At 11,000 Ft. above Sea-Level

The Ophir Loop—The Village of Ophir in the Valley Beyond

above the timber-line. It was wearisome pulling unwilling horses over talus slopes, so we soon halted for a breathing space and took in the view. An amphitheatre of rugged peaks formed our background; tiers built up of successive extrusions of andesite looked out upon a vast lifeless desolation of gray summits and dun-colored ranges, from which rose three flaming peaks, red as torches to anarchy. These, the Red mountains, are a landmark throughout the region. Their color is due to the solfataric action of thermal waters upon the iron sulphides disseminated through andesitic rock.[21] At the foot of these iron-stained ridges are situated the famous Guston and Yankee Girl mines, which were so productive about fifteen years ago. The origin of the lodes is connected with that of the peculiar red summits, in that both are traceable to the activity of acid waters, which have precipitated rich silver minerals on the one hand, and, on the other hand, have removed the more soluble portions of the andesite, depositing additional silica, so that the resulting quartzose country has withstood erosion sufficiently to survive in the form of red summits, which now serve as beacons to the prospector.[22]

We reached Silverton before dark.

[21] 'Notes on Some Colorado Ore-Deposits,' by S. F. Emmons. *Proceedings* Colorado Scientific Society, Vol. II., pp. 93-99.

[22] This matter has been much discussed. See Theodore B. Comstock, 'The Geology and Vein-Structure of Southwestern Colorado.' *Transactions* American Institute of Mining Engineers, Vol. XV., pp. 252-264. Also S. F. Emmons, Vol. XVI., p. 809, and T. B. Comstock, Vol. XVII., pp. 261-264.

Chapter 10

SILVERTON AND ITS EARLY HISTORY — THE FIRST SMELTERS IN COLORADO — PIONEERS OF INDUSTRY — SOME WELL KNOWN NAMES — RAPIDITY OF DEVELOPMENT.

SILVERTON exhibited a condition of bustling activity; the country tributary to it, up and down the Animas and along its tributary streams, has recently undergone a good deal of that new development which is essential to the maintenance of production in a mining district. In fact, by reason of the energetic development, particularly of gold mines, which has been going on ever since the fall in the price of silver in 1893, the surrounding region is today one of the most prosperous mining tracts within the Rocky Mountain area.

The mountains around Silverton were first invaded by the pioneers in 1871, when the Little Giant vein was discovered by Miles T. Johnson. In 1872 an *arrastre* was put up, not far from the present site of the large modern plant of the Silver Lake mine. At that time the nearest trading station was at Conejos, in the San Luis valley. Until 1873 the

SILVERTON

Indians had legal control over the region, but this was ended peaceably by the Brunot treaty.

Early on the morning of September 9 our party of four rode down the wide main street on the way to the Golden Fleece mine, near Lake City, about 40 miles distant. Just outside the town the road passes the entrance to Cement creek. Here there is a new pyritic smelter, which is close to the site of the old Green smelter, erected by Judge Green, of Cedar Rapids, Iowa, in 1874. The machinery for that early metallurgical establishment came on mule-back from Colorado Springs, over 300 miles; Colorado Springs being at that time the terminus of the railway. The first furnace was made of sandstone without any lining, and Mr. John A. Porter has told me of the advantages and disadvantages of this method of construction. It had one advantage: when the silicious portion of the charge was insufficient for a good mixture, the side of the furnace contributed the silica that was wanting! In 1876 the first water-jacket used in Colorado was put into service at the Green smelter; it was a round jacket three feet in diameter and was made by Fraser & Chalmers, at Chicago. The year before, in 1875, Mr. Porter had put in a siphon-tap, suggested by his experience at Eureka, Nevada, from which place he had come to Silverton. This was the second siphon-tap employed in Colorado; the first was applied at the Swansea works, near Denver, by Ahrents. Nothing remains of the old Green smelter save a cabin with a brick

chimney, which used to be the assay-office of the establishment. This plant was the parent of the San Juan smelting works at Durango, erected in 1880, and contributed an important share to the early development of the surrounding region.

Local smelters such as these have helped the exploration of the mountains. In riding across country, as we were doing, one would occasionally see, in contrast to the bright coloring of the aspens, a black patch of ground, suggestive of the gloomy gulf down which Pluto snatched the fair Persephone. These dark patches are old slag-dumps, which have crumbled to dust, and serve as reminders of the little smelters that preceded the large centralized establishments erected in later years at Pueblo and Denver. The memory of these early efforts has crumbled away, like their slags, but they are interesting not only as small beginnings of a great industry but on account of their human associations. They served to train many of our best men. John A. Porter has been mentioned in connection with the Green smelter; at the Rico works, first built under the name of the Grand View smelter, in 1879, such men as F. M. Endlich, Hofman, and Arnold successively got experience and, in much later years, W. C. Brace, E. J. Wilson, and L. D. Godshall. The early seventies in Colorado saw the beginning of many reputations that are now well established. Dr. Edward D. Peters is said to have been a great champion of the reverberatory in those days; he built a smelter at Dudley, at

the foot of Mt. Bross, in 1872. The ores were rich in silver and copper, but loaded with heavy spar, so that although he began with only a calcining and stone blast-furnace, 36 by 42 inches in section, with water-cooled tuyeres, he subsequently added a reverberatory furnace, having a 9½ by 15-foot hearth, which was fired with spruce wood. The ores were unfit for smelting by themselves, but the smelter was operated with moderate success for two years. At that time West was in difficulties with a matte blast-furnace at Black Hawk, and Collom was bucking against the impossible zinc-silver ores of Georgetown at a little smelter just below Empire, near the forks of Clear creek.

Colonel William L. Chandler was at Saints John, in Summit county, just over the continental divide, where the ore from a mine at Keystone was made into a silicate of lead in the fusion-hearth of a roasting reverberatory furnace. This was called 'matte' and was treated in a low shaft-furnace; the height from the tuyeres to the charging door being five feet. This stuff was sent to Empire, where John Collom was running the small shaft-furnace already mentioned. The treatment was a failure until H. A. Vezin took charge of the works and produced good silver-lead. This was early in 1872 and was the first lead produced on a commercial scale on the Atlantic slope of Colorado. In 1875 Anton Eilers took charge at Saints John, but left in a short time in order to join Billings at the Germania works at Sandy, near

Salt Lake City. He was succeeded at Saints John by Franz Fohr, who, in later years, was manager of the Harrison Reduction Works at Leadville.

In 1874 Mather & Geist started their smelter at Pueblo with two furnaces. This was the beginning of the Pueblo Smelting & Refining Company. A certain Professor Cheney at Animas Forks and a Professor Durier at Animas City erected smelting furnaces in localities as ill situated for fuel as for ore—doomed, therefore, to point a moral and adorn a melancholy tale.

Richard Pearce had his first experience in Colorado in 1873, at an unsuccessful smelter erected near Empire, on the site of Collom's old works. At the end of 1873 this ill-fated establishment closed and Mr. Pearce moved to Black Hawk, where Professor N. P. Hill, not long arrived from Brown University, was in trouble with the pyritic ores of Gilpin county. Pearce and Hill joined forces and, under the advice of the former, an addition was made to the plant, whereby it became possible to treat the matte, which up to that time had been shipped to Vivian & Sons, at Swansea, Wales. This change of method made the Black Hawk smelter a financial success, and led, finally, in 1878, to the erection of the large plant at Argo, near Denver, where, under the name of the Boston & Colorado Smelting Company, it has since become so well known.

James B. Grant had been recently graduated from Freiberg when, in 1878, he built a small one-stack

smelter at Leadville. Within a year this was increased to eight stacks; and in 1880 Edward Eddy and W. H. James, who owned sampling works at Leadville, joined Mr. Grant in his smelting venture. That pioneer establishment is gone, but it was the parent of the Omaha & Grant Smelting & Refining Company. Anton Eilers has been referred to already. He was at the Germania plant from 1876 to 1879; in the spring of 1879 he started grading for the Arkansas Valley smelter, which was blown in on May 20 of that year.

In these early efforts there is a personal equation and a human interest lacking in the larger undertakings of later days, because they represented the skill, hopefulness, and energy of individual young men, many of whom have proved to be masters of the metallurgical art. While it must be amusing to those who are accustomed to the more patient progress of older countries to read of a period within the memory of active men as being 'historical,' yet, as time is measured in a rapidly progressive mining region like Colorado, it does indeed seem long ago. "In a remote period of Western history, that is to say, 30 years ago," is a sentence not without a touch of humorous exaggeration to a European, but the rapid achievement of a new country outsteps the slow beat of the pendulum.

Chapter II

THE NORTH STAR AND SILVER LAKE TRAMWAYS—SOME CLEVER ENGINEERING—COMPARISONS—DOUBLE AND SINGLE ROPEWAYS—EUREKA—VETERAN MINERS.

AS we rode along the right bank of the Animas, we passed the North Star mill, where John J. Crooke employed the old Augustin process, roasting silver ore with salt and leaching the resulting chloride with hot water, finally precipitating the silver on copper in the approved way.

Farther up we came upon the Stoiber residence, 'Waldheim,' a 30-room house, with all modern appointments, built by the former owners of the Silver Lake mine. Just beyond, in Arastra basin, we could see the Silver Lake mill and the tramway, which extends in swinging lines to the mine beside the lake at 12,250 feet above sea-level. One of the spans of this Bleichert tram clears a distance of 2,200 feet. In a total length of 8,400 feet, the upper division of the tram descends 2,100 feet, and has only 19 supporting towers. The lower portion—from the old mill to the new mill—is 6,200 feet long, with a

fall of 659 feet. The tram from the Iowa mine climbs the neighboring bluffs, and a little further up the Animas the North Star tram reaches the river from near the top of Sultan Mtn., a height of nearly 13,000 feet, making a descent of over 3,200 feet. Silverton itself is situated at 9,300 feet above sea-level.

The North Star tram is two miles long, and connects the mill on the right bank of the Animas with a loading station at the entrance of an adit at 12,900 feet above sea-level. A two-bucket tramway, having a single span of 1,950 feet, carries the ore to two large storage bins situated in a gulch 604 feet lower down. Each of the two buckets carries 1,300 pounds of ore, the empty one being pulled up by the descending loaded bucket. The cable descending is 1⅛ inch in diameter, while the rope that carries the empties is 1 inch.

The ore-bins, just described, serve as the terminal of a Dusedau aërial tramway, which goes to the mill, two miles down the mountain, making a vertical descent of 2,600 feet. At an altitude of 12,300 feet the tram crosses a mountain lake with a span 1,340 feet long, and lower down there are other spans of 1,050 feet and 1,030 feet, respectively. At the lower end, connecting with the mill, the final span is 900 feet long, with a fall of 380 feet, crossing the Animas river at a height of 150 feet above the water. The tension station is midway between the mill and the upper terminal. It is said that the gradient of the installation is such that 30 horse-power is developed; but this power is not utilized.

The buckets or cars are 40 in number, and each carries 600 pounds; they are placed at intervals of 600 feet, and travel at a speed of six feet per second. Fifty towers are stationed along the line, the highest being 71 feet. Two miles of steel ropes are used for this system, the total weight of them being over 30 tons.

These numerous aërial ropes, spanning the intermountain spaces like great spiders' webs, are an important feature of mining in the San Juan region. We had already, on the previous days of our trip, seen the trams of the American Nettie, Bright Diamond, Grand View, Camp Bird, Smuggler Union, Columbia, and Liberty Bell mines, beside others, the names of which we did not know, so that with the group of three just referred to, near Silverton, we had, in the aggregate, observed a good many examples of this kind of mountain engineering. Most of the recent installations belong to the Bleichert and Otto systems, in which the bucket is drawn over a thick stationary cable by means of a smaller traveling rope. The traction rope is usually from ½ to ⅝ inch in diameter, while the fixed cable is from 1 to 1½ inches. The older Huson and Hallidie systems, with a single traveling rope, to which the small buckets are attached, are nearly obsolete except for short distances and over easy contours. The need for frequent supports, the consequent less substantial construction, and their smaller capacity have rendered them less desirable as a means of transporting ore

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Rope Tramways

A Loading Terminal

Bucket Attachment

The Webber Grip

over a rugged country. Experience now favors the double-ropeway system in spite of a cost of installation that is 30 to 50 per cent greater than the single-rope type, because this difference of initial expense is soon wiped out by the cost of maintenance, which with the Hallidie type is nearly double that demanded by the Bleichert; moreover, in the matter of capacity, it may be said that the former is limited to, say, 75 tons per day of 10 hours, while the substantial construction and larger scale of the latter permit of a capacity that ordinarily reaches from 250 to 400 tons per day of 10 hours.

On the other hand, it is claimed[28] that in a tramway using the friction or compression grip, the rope will stretch after it is in use, and when this occurs the rope is reduced in diameter, so that the grip-jaws do not hold the bucket tightly, with the result that they slip and accidents ensue. This feature is avoided in the Leschen tramway, which uses from two to four bands that encircle the rope and take care of this difference in diameter within reasonable limits, for, by tightening the bands they become as snug as the original arrangement. When a bucket is attached to the cable by a friction grip, it is done suddenly, and gives the rope and the entire equipment a jerk or jar. The operation consists in first moving the bucket to the desired attaching point, and the rope, running through the grip-jaws, wears them away,

[28] In correspondence received by the author from A. Leschen & Sons Rope Company of St. Louis.

and then, when the grip is closed, it receives the sudden jar referred to.

The particular objection to a tramway using a friction grip is that the traction rope is supported on rollers, the latter being placed below the bucket, so that when a bucket passes over a support, it clears it. The bucket, however, in passing raises the traction rope about four feet. The cable then gradually lowers after the bucket leaves the tower. The result of this is not so apparent on a level tramway, but where there is grade, and especially where there is a cliff or a long span, the strain produced in the buckets in order to raise the traction rope to the proper height is excessive, and will not only injure the traction rope, but it also affects the fixed cable immediately above. In the tramways employing a clip, such as the Leschen type, the traction rope is supported on sheave-wheels placed at the same relative distance as that of the bucket to the cable. In other words, the traction rope remains in the same vertical position at all times, and the clip or lug is so constructed that it passes over the sheave.

Owing to the fact that in a tramway provided with the friction grip a bucket cannot operate around the terminal stations while being attached to the rope, it becomes necessary (upon detaching the bucket at the terminal) to move the bucket around each terminal by hand. The labor required to do this depends upon the capacity of the tramway. In the Leschen tramway, the buckets remain attached

to the traction rope when traveling around the terminals. Only one man is required, and he is placed at the loading terminal to handle the brakes and to control the flow of ore into the buckets. An argument in favor of the friction-grip tram is that, by having no lug on the rope, there is no bending of the cable at the lug, so that the rope will last longer. This is denied, however, it being claimed that there is less wear on the rope near the button than there is at any other place along the line; in fact, the clip is said to protect the cable. The effect that the clip has on the rope is said to be less than that produced by a friction grip. The various kinds of clip or button in use are so arranged that they can easily be moved from one position to the other on the cable in case this is desired, and provision is made for turning the rope so as to distribute the wear evenly.

The first cost of a tramway of this kind depends upon the contour of the country traversed, and the distance from the manufacturer who supplies the material. In the high altitudes of the San Juan, say, 10,000 feet or over, the cost of material for an installation having a capacity of 200 tons per day of 10 hours would be about $2.10 per foot of tram-line, and the cost of freight, plus erection, would be about $1.15 more, so that the total cost would be about $3.25 per foot. A tramway, one mile long, having the capacity mentioned, would entail an expenditure of about $20,000. Actual expenditure for tramways in this district has ranged between $2.50 and $8 per

foot; as a rule the cheap one proves the most expensive on account of the greater cost of maintenance and repairs. The Camp Bird tramway is 8,550 feet long, with an angle station; the fall, in the length mentioned, is 1,840 feet, and the cost, all told, was $55,094. It is a thorough piece of engineering work. At the present time it is worked on two 8-hour shifts, with a duty of 210 tons per diem. The operating cost is 17.6 cents and the maintenance 1½ cents per ton. A large amount of material is sent to the mine, as a back load, and the cost of handling this also is included in the figures just quoted.

The spacing of the supporting towers is of course governed by the contour of the ground. In this regard the double-ropeway systems, with their independent fixed cable for bucket-track, permit of a comparatively more direct path and more uniform movement of buckets, because the cable can be stretched to a high tension, diminishing the deflection in the swing of the cable. In the case of the single ropeways, which both carry and propel the bucket, as a high tension leads to overstraining of the rope, it is avoided, so that there is greater dip in the cable and need for a larger number of supports. This is a decided drawback in a rugged mountain country.

The automatic feature of tramways is apt to be exaggerated. For instance, it is the opinion of certain capable managers that it is a mistake to depend too much upon gravitation, and that auxiliary steam-power will permit of the exercise of better control over

the operation of the tram and the possibility, in consequence, of running it at greater speed. There is no doubt that an engine acts as a useful governor; on the other hand, the attempts to harness a rock-breaker to a tramway marked by excessive gravitation have failed, because a rock-breaker in operation is essentially a variable machine in its consumption of power. On the other hand an air-compressor has not this bad feature, and if a tram worked against an air-receiver it would have a self-adjusting governor of a useful kind. Most of the breakages, and much of the hard wear and tear, are due to variations in speed and bad control of tramways that have a difficult contour.

In this connection it is well to point out that the modern tram owes much to the better modes of attaching the bucket to the rope. The use of clips or lugs permanently fixed to the rope and employed as attachments for the bucket was found to develop uneven wear in the cable, and this method had the further drawback of hindering a change in the spacing of the buckets whenever wanted. The modern attachment grips the rope wherever desired, so that the bucket is hung at the will of the loader, and never exactly at the same spot.

We continued on our way up the valley of the Animas and soon passed through Howardsville, which figures largely in the early reports made by R. W. Raymond, F. M. Endlich, and other Government officials during the 'seventies. It is now chiefly populated by Mr. Tom Trippe. In Cunningham gulch,

which is close by, the andesite-breccia of the San Juan formation comes down to the Algonkian schists. Several mines, such as the Highland Mary, Ureteba, and Green Mountain, exhibit this contact between Tertiary and pre-Cambrian terrains. The best ore obtained from the lodes, which penetrate both formations, is said to have come from the schist just below the breccia; this was especially the case with the Green Mountain vein, which had a large orebody immediately under the volcanics. The next tributary valley is Maggie gulch, where there are several young mines, one of which, the Ridgeway, is of importance.

The Animas valley swings around to the north, and the road brings the traveler into the main street of Eureka, the distributing point for the Sunnyside, Mastodon, Silver Wing, and other mines that have proved productive. Just as Tom Trippe occupies Howardsville, so Rasmus Hansen represents Eureka. These are among the very few of the pioneers who are still actively at work—strong brave men, who have crowded the romance and vicissitudes of mining into their own lives; men with an indomitable pluck and a tireless activity, like that of the torrent of the Animas, which rushes by their cabin doors, sweeping past with a vagrant energy that heeds neither the gladness of the radiant valley nor the gloom of the savage gorge until, after many wanderings, it abates its speed and hushes its voice in the still waters of the darkly flowing San Juan.

Chapter 12

THE CINNAMON PASS — ELECTRICAL TRANSMISSION OF POWER — THE TABASCO MILL — BURROUGHS PARK — THE SECONDARY ENRICHMENT OF COPPER VEINS.

BEYOND Eureka we passed the Silver Wing and the Tom Moore mines, and just below Animas Forks we turned eastward and started the ascent of Cinnamon pass. This is at an altitude of 12,600 feet, and separates the watershed of the Animas from that of the Lake Fork of the Gunnison river. On the divide is the Isolde mine, in the andesite-breccia, also the Bon Homme, in granite, and lower down we passed the tramway being constructed for the Tabasco mine. The bright glint of a thick copper wire bespoke a line of electrical transmission connecting the mine and mill with a power station situated on the farther edge of Burroughs Park. As the copper wire caught the sunlight I was reminded of the aid given by one metal to the other; the electrical transmission of the energy of water has done much for gold mining at high altitudes, where fuel for steam-power generation entails a cost that is almost prohibitive. Several successful installations have been

made in the Silverton district. The application of this form of engineering was limited until recent years. As long as the direct current only was available the transmission of power by electricity had severe restrictions, because under that system the practical limit was 700 volts,[25] and it was not possible to augment this by the use of transformers. Since the introduction of the alternating current these limitations have been swept away, and the voltage can be raised to a degree the practical limit of which is dependent upon the insulation of the transformers. In practice, the voltage is usually raised so that the power can be transmitted over a wire not smaller than No. 5, because that size gives the lowest investment in copper. The old and the new systems of electrical transmission can be compared by stating that an alternating current at 2,000 volts would require only one-sixteenth of the copper that would be required by the same current at a pressure of 500 volts transmitted by a direct current, per horse-power, per given distance, and at a given loss. The cost of power, as sold by the large generating companies in the mountains, to the mines at timber-line or near it, averages about $8 per horse-power per month.

The advantage of electrical transmission of power in place of the painful transport of fuel to the

[25] Although the Virginius mine uses 900 volts. This plant was erected before the introduction of the multiphase alternating current, and the high cost for copper wire over a four-mile line prompted the adoption of this unusually high pressure for a direct current.

A Pack-Train on the Way to the Old Hundred Mine
in Cunningham Gulch, near Silverton

THE FIRST SNOW

SILVER LAKE TRAIL

mines above timber-line can be gauged by a look at the trails, which frequently afford the only means of communication between the valleys and the mines. This is well illustrated in the accompanying photograph[26] of a trail to one of the Silver Lake group of mines.

The Silver Lake installation was the first multiphase plant in the San Juan region. It was erected eight years ago, and operates a great variety of machinery, such as drills, pumps, hoists, blowers, machine-shop, etc. The line is three miles long. A compound condensing engine has replaced water-power because the generating station is on the railroad, so that coal can be delivered cheaply (it comes from near Durango), while the water-power available was both insufficient and precarious on account of the damage to the long flume, brought about by rockslides, snowslides, and the other difficulties of a high altitude subjected to violent extremes of heat and cold.

Below the Tabasco mill we met a wagon heavily laden with bed-plates for an engine, bearing the name of the Colorado Iron Works; and soon afterward, riding through a belt of pines, we found ourselves in the open valley of Burroughs Park. This district has been, during the past two years, the scene of active prospecting and some mining. We dismounted and partook of hospitalities tendered by

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[26] *Transactions* American Institute of Mining Engineers., Vol. XXVI., p. 423.

Mr. George Peirce, who subsequently piloted us to the Cleveland group of veins. These are not as yet of economic importance, but they have characteristics that are interesting from a scientific point of view. They penetrate granite; the Monticello vein, which I saw, was about one foot thick; for the first 15 feet in depth the vein consisted of cellular quartz marked by copper stains, but otherwise it was said to be barren; lower down it became metal-bearing, and at about 45 feet deep I found a piece of copper pyrite coated with a gray film of chalcocite, suggestive of secondary enrichment and reminding me of certain experiments made by Mr. H. V. Winchell at Butte, in the course of which the copper of a slightly acid solution of copper sulphate, containing also some free sulphurous anhydride (SO_2), was found after a time to have precipitated a film of gray copper sulphide upon the bright facets of crystals of copper pyrite.[27]

In the afternoon we left this locality and rode down Burroughs Park and along the Lake Fork of the Gunnison until, in the evening, we pulled up at the Golden Fleece mine, beside lake San Cristobal. The road at first goes over granite covered with an occasional patch of andesite-breccia, such as the one in which the Champion mine is situated. Then it cuts into the Algonkian schist and quartzite. Just

[27] These experiments have been described in detail lately. 'The Synthesis of Chalcocite,' by H. V. Winchell, *Engineering and Mining Journal*, May 23, 1903.

before reaching the lake the road and stream approach close to the contact between upturned schist and the overlying andesite-breccia. Near the lake, decomposed andesite-breccia becomes the prevailing formation. The road follows the contour line of the lake shore and afforded us a glorious canter in and out among scattered young pines; there came glimpses of placid water reflecting the resplendent coloring of the aspens that clustered upon the encircling hillslopes, and the bright warm tints of clouds that caught the sunset glow. Suddenly, in turning a corner, the road ran among a group of cabins and other buildings, the busy aspect of which told us we were at our destination, the Golden Fleece mine.

U. S. G. S.

Chapter 13

THE GOLDEN FLEECE — A BONANZA AND ITS VICISSITUDES — GEOLOGICAL FEATURES — THEORIES OF LODE FORMATION — THE TREATMENT OF THE ORE.

IN the summer of 1896 the Golden Fleece mine shipped nine carloads of ore, weighing about ten tons each, the poorest of which netted \$33,000 and the richest \$49,500. In a few months the bonanza yielded \$1,600,000. This rich ore was characterized by petzite (Au, 25%; Ag, 41%; Te, 34%) and ruby silver (proustite) scattered through a dark chalcedonic quartz or hornstone.

The story of this mine exemplifies the uncertainties of digging for gold. In 1874 Capt. Enos T. Hotchkiss, connected with a government surveying party that was laying out a toll-road from Saguache to Lake City, caught sight of the outcrop, standing conspicuously above the hillside, and examined it. He located it as the 'Hotchkiss' mine, and had some assessment work done while he was engaged in his survey-work in the vicinity. As far as is known, he found no ore. A year later, when Hotchkiss had abandoned his claim, it was re-located by George

Wilson and Chris Johnson, under the name of the 'Golden Fleece.' They began what is now known as the No. 1 tunnel, but finding only little stringers of rich ore they ceased work. Others did similar desultory prospecting. O. P. Posey found a rich patch of ore in the croppings above the No. 1 tunnel and took out several hundred pounds, which were packed to Del Norte and sent thence to the Pueblo smelter. Then John J. Crooke took a lease and bond; he also extracted about $30,000 from the outcrop above No. 1 tunnel, which had been extended a little farther, without result. This was between 1876 and 1878. In 1889 Charles Davis took a lease and bond; he did a good deal of work along the high croppings, and finally sank a shaft 30 feet deep, which struck a body of ore yielding $40,000 in a short time. Late in that year, 1889, George W. Peirce bought the mine for $50,000, and commenced vigorous exploration. He found out very soon, indeed, that Davis had extracted all the ore in sight, and the outlook was not cheerful. All the work up to this time had been to the north, on the supposition that the vein had been faulted in that direction. The new owners cross-cut south at the No. 2 tunnel, which had been previously extended a little way, but had found nothing. The vein was picked up, but not much ore was encountered at first. They persisted, however, and within a year rich ore was cut on No. 2, and it was traced upward until it became easy to intercept the same body at No. 1. It was discovered that the former owners had been

Fig. 8.

THE TOLL ROAD BETWEEN OURAY AND SILVERTON

THE VALLEY OF THE UNCOMPAHGRE.
Ouray in Middle Distance; the Montrose Mesas Beyond.

within ten feet of the main orebody of the mine, which from that time, and until 1897, was highly profitable.

The Golden Fleece vein strikes east and west, approximately; it dips southward at the rate of 33 feet in 380 feet. In depth it flattens, so that the hade for the lower workings becomes 150 feet in 1,120 feet. In the accompanying drawing, Fig. 8, the upper workings and the geological conditions are both represented. The vein penetrates fine-grained breccia and tuffs, of the San Juan formation, until it runs abruptly into a coarse breccia, where it scatters and ends. The coarse breccia lies on the top of the finer series at an angle of 28°; the difference in the rate of erosion renders the change of rock easy to recognize at surface, even if the abrupt cessation of the conspicuous outcrop did not incite close observation. The outcrop makes a comb, as much as fifty feet in height, of hard sintery quartz, which, on examination, is readily seen to be a decomposed and silicified breccia, exhibiting various degrees of silicification from the vein itself, which is almost entirely quartz, to the outer country, in which the original structure is but slightly obscured. In this outcrop there have been—and still are—found irregular patches of extremely rich ore. In the underground workings it can be seen that the vein itself follows a line of fracture and brecciation; the twice brecciated country has been re-cemented with silicious waters, so as to form a 'vuggy' or cellular veinstone. Pieces of country are to be seen enclosed within a coating of quartz. The

sheeting of the rock explains the multiplicity of walls and ore-seams that confused those who have at various times exploited this vein.

The outcrop ceases when the vein encounters the coarse breccia; so, also, in the underground workings the vein itself comes to an end with a suddenness that is, however, only comparative. The contact (*A B*) has been considered a fault; a good deal has been said concerning its regularity and clean-cut character. This, however, does not, I believe, accord with the facts. The so-called 'fault' is not a break or dislocation in the rocks; it merely marks the division between the layers of fine-grained breccia and an overlying formation of coarse breccia; there is no smooth plane or wall or defined parting between these two formations, but only a sudden transition which at a distance is more marked than near-by.

The orebody of the mine was found in a triangular block of ground bounded on the one side by this 'contact,' *A B*, on the other by the hillside, *B D*, and along the base by the No. 3 tunnel, *A D*. The outcrop was patchy and impoverished by leaching, the evidence of which is marked. This robbing of the croppings probably enriched the vein a little lower down. A branch vein, called the Ilma, which comes in from the northeast, appears to have played a part in determining the eastern or outer limits of the orebody.

Speculation concerning the causes that determined this occurrence of rich ore is not hampered

by too many facts. A correct explanation suffers from the lack of them. The contact existed before the vein was formed. The fracture, followed by the ore, passed easily through the finer-grained rock, but ceased abruptly when it met the beds of coarse breccia, because the force of fracturing was not only insufficient to overcome the resistance of the harder fragments contained in the latter, but it must have been dissipated by the encounter with a loose-textured body of rock, much in the way that the power of a diamond-drill becomes wasted in passing into a shifting mass of loose conglomerate. As a consequence, the energy of shattering was diverted along the contact, the vein-fracture ceased, and the later ore-depositing waters were barred from farther advance into the coarse breccia, save as a scattering confined to the neighborhood of the contact. At the third level, the orebody, which here is in the fine-grained country, was notably wider immediately at the 'contact,' and in examining the outcrop of the vein I noticed that it was difficult to decide upon the exact line of separation between the two formations, because the mineralization extended from the fine into the coarse breccia so as to obscure the divisional plane.

The deeper levels have found some small bodies of ore, and a good deal of money has been obtained from isolated pockets all the way down to the main tunnel or adit, about 700 feet below the third level. Several larger bodies of low-grade ore have also been

encountered in the deeper workings. Exploratory work is still going on, especially near the contact, where the chances for finding more ore seem to be reasonably good.

Most of the rich ore of the Golden Fleece mine was shipped to the smelters, but the low-grade mill-stuff was treated on the spot. As the valuable metals were chiefly contained in telluride minerals (principally petzite, but also some hessite) the treatment—by concentration—presents features of interest. The mill was of latest design, erected by Stearns, Roger & Co. It consisted of rolls for crushing, Huntington mills for re-grinding, Wilfley tables for concentration, and a canvas plant for the treatment of slime. No use was made of amalgamation. The Huntingtons were provided with screens of 30 mesh, and experience showed later that 20 mesh would have been better. In treating 18,000 tons having an average assay-value of $10.25, half of which was in gold and half in silver, the extraction averaged between 45 and 60%; 63% was the best result. The concentrate contained 55 to 65 oz. silver, 1 to 3 oz. gold and 12 to 18% lead, in the form of galena. The concentration was in the ratio of 12 to 1. It may be said that the experience with this ore indicated conclusively that a simple mill,[28] with Wilfley tables and an extended canvas plant as the principal features, would have been adequate.

[28] The mill was really designed for an ore containing galena and iron pyrite, both of which proved unimportant ingredients when the mine became further developed.

Chapter 14

SLUMGULLION GULCH — LANDSLIDES — THE CANNIBAL PLATEAU — A GRIM TALE — ROCK DISINTEGRATION — ACTION OF FROST.

WE remained for two whole days with Mr. Peirce, and early on the 12th of September our journey was resumed. In crossing the valley of the Lake Fork of the Gunnison one cannot help noting the peculiarities of the surface. The eastern range, opposite the mine, is marked by a depression known as Slumgullion gulch. As seen from No. 3 tunnel it looks like a big landslide, the steep slopes of which have been obscured by weathering. However caused, it has reached down to the valley and dammed the stream so as to form lake San Cristobal. It is said, by those living on the lake shore, to be still in motion and to be extending farther across the valley.

Slumgullion is commonly imputed to glacial action, but the observed facts do not require us to go so far afield. Landslides, some of them of great extent, dating back to early Pleistocene time, have been recognized and carefully studied in the Telluride and Rico regions. They are attributed to the penetration of water along bedding-planes and other lines of part-

ing. In the case of Slumgullion the porosity of the coarse layers of breccia permitted the entrance of water, which would reach down until a less porous stratum was encountered and then, if the dip-slope were toward the valley, the conditions would be ripe for a landslide. The geological conditions observed in the Golden Fleece mine would favor such movement if the bedding-planes dipped with the hillside; they dip right into the hill, however, and as a consequence the surface slopes steeply, at 30° and over. The same geological structure if carried across to the *other* side of the valley would explain the landslide of Slumgullion. In the earlier history of these mountains they were bolder than they are now, and when, at the close of volcanic activity, earthquakes supervened, then the landslides occurred on a colossal scale and were accompanied by a shattering of the rocks, covering areas extending over many square miles.

The ascent of Slumgullion was easier than it sounds, and as we filed along we were reminded by the mention of the Cannibal plateau, rising in bleak ruggedness to our left, of a tragedy the details of which no human witness has truthfully told. In 1873 a party of prospectors, intending to go to Fort Garland, in the San Luis valley, found their way up the river which we had left. It was a very severe winter, so that game was scarce; they were verging on starvation, and on their last legs. Out of the five men, one, named Parker, survived; he claimed that he went out into the woods hunting and on his return one of his

comrades, rendered mad by hunger, attacked him with an axe, so that he had to shoot him in self-defense. Then the other three set on him, so that he had to kill them also. It is generally believed that Parker killed them to get the money they are understood to have carried. Game was not as scarce as he represented; at all events he managed to support himself until he worked his way out, and finally reached Durango, where he was subsequently arrested, convicted, and sentenced to imprisonment for life. Two years ago he was liberated by the then Governor of the State. In his gruesome story he confessed to having been compelled by hunger to eat portions of his victims; hence the ominous name, which, like the gloomy brow of the Cannibal plateau itself, overshadows the fair valley of San Cristobal.

At the top of Slumgullion gulch the road turns eastward to Creede; we turned northward and, picking up a trail that plunged into a pine forest, we eventually found ourselves at the headwaters of the Cebolla and followed it down. We were soon on a well-beaten path—the old Ute trail, used by the Indians in their migrations across the Gunnison country. They are gone from these hills and are now huddled on the reservation; so also the game which they hunted; that too has been driven away by the restless prospector. As we rode along in single file there was no sign of living thing for hours of travel; we followed the Cebolla, fringed with willows and threading narrow valleys overshadowed by cliffs of architectural

aspect, battlemented masses and monumental pillars, like Egyptian pilons, among which a babbling trout-stream took its quiet way. The mountain flanks appeared to be built of rhyolite and rhyolite breccia. Occasional fragments of obsidian were found. Later we were in a granite country.

While picking our way over the talus at the foot of high cliffs and noting the general air of destruction that had characterized much of the rock structure seen during this particular morning's ride, it was impressed upon the observer that frost action was the chief agent of disintegration. To most people who travel among mountains, and even to those who live at their feet, it is often a wonder how the rocks are broken, and when. Anyone who sleeps outdoors will note the fall of rock-fragments during the night, and to this fact, I think, is due the general immunity from such danger. The patient leverage of the frost is the chief agent in disintegrating the rocks, for, the maximum density of water being at 4° C. or 39° F., one of the most powerful of nature's silent forces is set to work upon the water, which, having sought out the cracks and crannies of the rocks, is in the act of expanding. By day the temperature in the high mountain country is raised by reason of the penetration of sunlight through the clear atmosphere, but at the approach of night there is a sudden cold, which is succeeded next day by another relaxation. During these variations of temperature the moisture in the rock-cleavages undergoes an alternation of con-

traction and expansion, which serves as an intensely powerful agent of disintegration.

At noon we pulled up at a spot marked in large letters on the map as 'Cathedral' and found a solitary log cabin with a hospitable woman in command, who gave us dinner. Subsequently, when smoking a soothing pipe, we could appreciate the simple grandeur of the granite forms, sculptured by Time and chiseled by the heat of day and the frost of night into buttresses and pinnacles simulating all the stern magnificence of a Gothic ruin—of a cathedral not made with hands, domed by the sky, and aisled with the green of the peaceful valley.

U. S. G. S.

Chapter 15

THE CEBOLLA HOT SPRINGS — THERMAL ACTIVITY IN THE ROCKY MOUNTAINS — ITS RELATION TO ORE DEPOSITS — THE GUNNISON PLATEAU.

LL of the succeeding afternoon was spent in a comfortable ride down the expanding valley of the Cebolla, which now began to exhibit cultivation, until, with a long gallop through the cool air of the twilight, we reached the Hot Springs. Here we put up over night. From a distance the patches of white incrustation and clouds of steam told us of our approach to this scene of thermal activity. The links between vein-formation and hot springs which are to be seen throughout this region are not lacking in suggestion. The mining districts of the Rocky Mountains are rich in hot springs. In Colorado there are Hot Sulphur, Idaho Springs, Manitou, Canyon City, Glenwood, Poncha, Wagon Wheel Gap, Pagosa, Trimble Springs, Ouray, and others of less importance. Similar conditions obtain in the States of Idaho, Montana, and Utah. The occurrence of these thermal springs, rich in alkaline and other salts, in the midst of a productive mineral region, is not without significance. Apart from their scientific aspect,

the hot springs play a useful part in the economy of man. They are the resort of people troubled with ailments requiring rest and change of food; to the miners, who come to them with rheumatism, indigestion, alcoholism, and similar troubles, they are beneficial, chiefly by reason of the opportunities for cleanliness, abstinence, and a simple diet—the last, to my mind, the especial boon of the thermal spring resort, because the miner lives in a world of sin and canned vegetables from which 'ranch food' and early hours of sleep will rescue him, bringing his inner man to a condition of normal healthiness.

Next morning, September 13, we turned eastward from the Cebolla valley and struck across country for Vulcan. At the foot of a high ridge we passed the Old Lot mine, cheerfully active. The dump indicated a vein carrying two or three feet of dark quartz streaked with galena. Close to the latter occasional specks of native gold could be seen—a handsome-looking ore. On the top of the ridge there was afforded an extensive view of the Gunnison plateau, bounded to the north by the deep gorge through which the swift Gunnison rushes, and to the south by the bold outlines of the San Juan mountains. Looking eastward the outlying summits of the Cochetopa hills broke the sky-line, but westward the sage-clad ridges stretched in sober gray until they faded into the blue of farthest distance. Though tame as compared to the grandly picturesque mountain-land from which we had just emerged, this plateau yielded a

pleasure of its own in the glorious spaciousness of a boundless horizon.

This billowy succession of rounded hills is built up of Archean granite and Algonkian schist. We saw several outcrops of the latter, especially in the Vulcan district. Flows of Tertiary lava and layers of breccia form occasional flat-topped ridges with broken edges and tumbled slopes of débris. The occurrence of an area of schist is an interesting feature, for although there are other stretches of these rocks, represented by the actinolite schist of the Arkansas valley and the hornblende schist of the western slope of the Sangre de Cristo, this particular rock is unusual in the mining regions of Colorado, and is not regarded as a favorable terrain for precious-metal mining, a fact which is in striking contrast to California, South Dakota, and other productive regions.

A Lode in Quartz-Schist. New Zealand.

Yellow Mountain. Early Snow

Chapter 16

VULCAN — THE GOOD HOPE MINE — GEOLOGY OF THE VEIN — NATIVE SULPHUR AND TELLURIUM — ACID WATERS — THEORIES OF ORIGIN —RARE MINERALS.

ON arrival at Vulcan we proceeded at once to the Good Hope mine, owned by Dr. Loui Weiss and others, who invited us most cordially to see the workings. This we did very gladly because the mine was well known as having been the source of the handsome specimens of native tellurium, which are to be found in many mineral collections; furthermore, I had heard of several peculiarities of lode-structure that aroused curiosity.

The Good Hope vein penetrates a greenish-gray sericite or hydrous mica schist, which has the greasy feel and fine texture characteristic of that rock. It forms part of the Algonkian series of crystalline schists that overlie the Archean granite of the Gunnison plateau. The vein has an approximately east and west strike; it dips northward, the hade being 40 feet in 500 feet. At surface the vein has an outcrop of heavy iron sinter, which eventually gives place underground to a band of country thickly impregnated

with iron pyrite. The walls of the vein are smooth and soft, both features being due to a parallelism with the schistosity of the enclosing country. No selvage or casing was noticed, but the lode-matter breaks rather readily away from the country on account of a blocky jointing, which, added to the fissile character of the rock itself, makes mining operations dangerous unless the timbering is well attended to. The rich ore is associated with streaks and lenses of iron-stained schist traversed by stringers of quartz. Native tellurium is frequently present, but the mineral that carries the gold has not been detected with certainty. I found some spots of petzite, and it is likely that this is one of the enriching minerals.

The accompanying sketch (Fig. 9) of the lode, as seen at the fifth level, will illustrate its structure. From *A* to *B* is the main pay-streak. On the hanging wall there are 3 to 5 inches of quartz, usually iron-stained; then comes a bleached decomposed schist carrying a little quartz throughout. It is this white silky schist that usually carries the telluride minerals. The band *B* is soft white schist, *C* is three feet wide and consists of massive granular-crystalline iron pyrite in finely shaded bands that reproduce the lamination of the schist. *D* is another band of bleached schist. *E* is similar to *C*, but not so solid. The enclosing country also carries a scattering of pyrite.

In the upper levels there is evidence concerning the origin of the vein and its contents. The occur-

rence of a body of native sulphur has been emphasized, practically, by its combustion to an extent that endangered the mine. The adjoining ground in the Chimney and Vulcan claims was abandoned on ac-

FIG. 9.

count of the burning of a similar body of sulphur. In the Good Hope there is a body of it 105 feet deep, 4 to 6 feet wide, and of a length which the owners thought it unwise to determine by further driving. The top of the sulphur nearly coincided with the first level, 90 feet from the surface. This substance, which

occurs as a grayish-yellow loosely coherent powder, was shipped in car-load lots to the Western Chemical Company, at Denver. It averaged 80 per cent sulphur and also 3 to 20 dwt. of gold per ton. The water of the mines on this vein is very acid and green in color. It carries over 1 % copper and 1.5 % sulphuric and sulphurous acids.

On inquiry I was given the analysis of the water from the shaft on August 15, 1901:

	Grains per gallon.
Sodium chloride	1.82
Sodium sulphate	3.39
Calcium sulphate	4.35
Calcium carbonate	4.61
Magnesium carbonate	6.52
Silica	0.23
Organic and volatile matter	3.67

The water contained no free sulphuric acid, or at most a trace; there was only a trace of copper. It is the opinion of Dr. Weiss that the sulphuric acid and copper now found in the water of the mine come from the adjoining Vulcan ground and are traceable to the effects of the burning of the native sulphur, which lasted for two weeks in the Vulcan and Mammoth-Chimney workings. There was no acid nor copper in the water from the Good Hope shaft until after the fire, and it is probable that surface waters have since then percolated through the Vulcan workings and thence downward to the fifth level of the Good Hope, which is 100 feet deeper than the Vulcan shaft. Apart from this fact, it is worth noting that the copper in

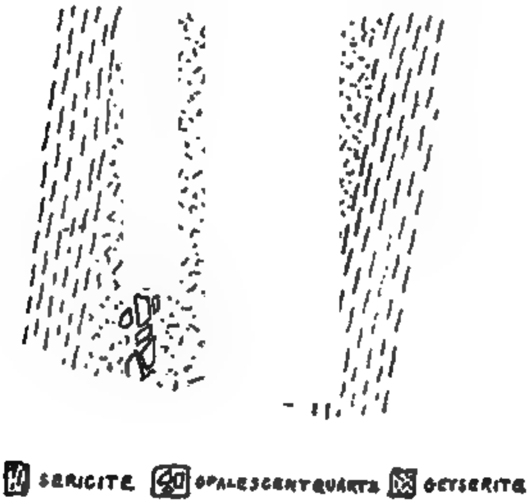
SERICITE
OPALESCENT QUARTZ
GEYSERITE

FIG. 10.


AGGLOMERATE
GEYSERITE

FIG. 11.

the Good Hope ore is increasing in amount with depth, specimens of the native metal having been found in the quartz from the lowest level.

At the first level there is evidence that the vein was shattered and that a certain part of it, at least, served as the vent for a thermal spring of comparatively recent date. Fig. 10 and 11 were taken, the first within 100 feet of the shaft and the other farther eastward. They exhibit the shattering of a vein of opalescent quartz and the filling of the vein-fracture with geyserite, for a width of four or five feet. The substance that is here termed 'geyserite' has a specific gravity of 1.96 to 2. It is porous, with scattered bits of opal within a mass of grayish-white crumbly hard non-crystalline silica. On comparing it with a piece of geyserite from the Yellowstone, the identity was apparent. The banded opalescent quartz, so abundant in the upper part of the vein, has all the characteristics of such a substance when deposited from thermal waters, and it occurs in the Good Hope vein in various stages of hardness and texture. Fire-opal is to be seen in occasional brilliant specks, and many varieties of dark jasperoid quartz are found, beautifully banded.

The gradation from geyserite to white sericite schist indicates that the latter contributed part of the material now occupying the vein-fracture, and the occurrence amid the silicious sinter of occasional patches of a smooth unctuous white powder suggests

remnants of the mica that characterizes the enclosing country.

These facts point irresistibly to the activity of thermal waters, that is, waters having a temperature higher than the mean annual temperature at the surface. Geyser action has, so Dr. Weiss tells me, been quoted in this connection by other visitors to the mine, but a geyser is a thermal spring that gushes[29] at the surface, and in this case we have no reason to suppose that such action occurred. Geysers are apt to be the last resort of a perplexed geologist. The supposition of thermal activity is based on the occurrence, in the vein, of substances that are actually deposited from the hot springs in the Yellowstone and other places.

In connection with this occurrence it is well to refer to the evidence of vein formation at hot springs, such as Walter H. Weed observed at Boulder, in Montana.[30] At that hydropathic establishment there are two groups of hot springs, issuing from fractures in the granite and having a temperature ranging from 120° to 164°. These waters do not form a surface deposit of sinter, but the fissures from which they issue are found to contain a mineral deposit. Many of the fissures have been sealed with this deposit so as to form veins, the outcrops of which enable

[29] Geyser is an Icelandic word, meaning literally a 'gusher.'

[30] 'Mineral Vein Formation at Boulder Hot Springs, Montana,' by Walter Harvey Weed, United States Geological Survey, 1900.

one to trace their course across the country. The vein-filling consists of a white or dark-gray material, which is mainly a mixture of chalcedony and stilbite, but also contains patches and bands of jasper, as well as included fragments of the granitic country. The illustrations given by Weed resemble the structure to be seen on the first level of the Good Hope mine. Opaline silica, in bands and curly layers, is seen throughout the mass. When freshly fractured it is usually dark-gray and very hard. The surrounding surface shows scattered fragments of jasper, chalcedony, and other substances evidently derived from these deposits. On analysis they were found to contain an appreciable amount of gold, as much as 0.05 oz., and silver, as much as 0.4 oz., so that the connection between ore formation and thermal activity is manifest. It is interesting to note that the author does not impute the source of the heat to 'unknown depths,' but to meteoric origin as "a part of the normal underground circulating water of the region, heated by physical conditions giving it access to the still hot rocks underneath."[21]

It would seem[22] that the Good Hope vein existed as a pyritic band in the schist, formed by the action of feebly active underground waters such as, with ex-

[21] *Op. cit.*, p. 250.

[22] The reader is reminded that these data were gathered during a visit of a couple of hours while on a horseback reconnaissance across the country, so that the writer's explanation of the origin of the vein is only a suggestion, prompted by the interesting features that have been briefly sketched.

Diorite Contact on Silver Mountain, near Ophir
Note Cabin in Right Lower Corner

Looking Down the Valley below Red Mountain

This is Ironton Park. The Saratoga Mill is on the Right

treme patience and slowness, are supposed to form similar lodes. Long duration of time for action and immense volume of solution compensate for feeble chemical activity and extreme dilution. The formation of the fracture occupied by the vein and the circulation of underground waters, which supervened, may both have come in the wake of dying volcanic energies, such as were manifested in the adjoining region of the San Juan mountains.

At a later date, after the Good Hope vein had been formed, it underwent a repetition of fracturing along which more intense thermal activity had play. A part of the vein served as a vent for a hot spring. This shattered the pre-existing vein and led to the decomposition of the pyrite, with the elimination of sulphuric acid, the formation of an iron sinter, and the accumulation of a large mass of native sulphur. It is also probable that the liberation of iron salts, such as the proto-sulphate, afforded solvents for the gold, which was re-deposited in the lower parts of the vein so as to make valuable ore.

The Good Hope vein is rich in uncommon minerals. Tellurium occurs native, as a tin-white mineral with a metallic lustre. Occasional specimens exhibit rhombohedral prisms. It is associated with petzite, the telluride of gold and silver, and a new mineral, the telluride of copper.[38] A greenish-brown mica-

[38] 'Rickardite, A New Mineral,' by W. E. Ford. *American Journal of Science,* Vol. XV., January, 1903. This contains 40.51% copper, 59.49% tellurium. The composition corresponds to the formula Cu_4Te_3.

ceous substance suggests roscoelite, a vanadium mica, which occurs in association with telluride gold ores in Boulder county, and at Cripple Creek, Colorado, as well as at Kalgoorlie, Western Australia. One specimen, secured on the occasion of our visit to the mine, contained fine needles of berthierite, a sulph-antimonite of iron, which bears some resemblance to stibnite. The opal of the upper levels is said to have been rich, especially in the purple-tinted spots; this may have been due to a telluride salt. The distribution of the tellurides, together with the native element itself, is another suggestion of the instability of these compounds in nature. As far as is known they are not characteristic of deep mining, but are more especially distinctive of that bonanza zone of gold lodes which is measurable from the surface and appears to be connected in origin with the conditions obtaining at the groundwater level. Of course, 'deep' is a relative term, and in this connection it refers rather to the vertical distance from the lower limit of oxidation than to the position relative to the surface.

Chapter 17

GUNNISON — THE DERELICT OF A BOOM — CRESTED BUTTE — THE IRWIN DISTRICT AND THE FOREST QUEEN MINE — SILVER VEIN IN SANDSTONE — ANTHRACITE COAL.

FROM Vulcan our trail took us over the eroded stumps of granite hills and across the river into the level stretch of country over which the town of Gunnison spreads itself drearily and wearily. Gunnison was a boom town, and when the wind goes out of a boom the wreckage is not enlivening. Between 1880 and 1885 there were three smelters at work. The combination, in the neighboring mountains, of iron, coal, and precious-metal deposits won for Gunnison the splendid title of 'a new Pittsburg.' The town attempts to cover an area of two miles square, so that when you think you are in Gunnison you are out on the prairie, and when you imagine you are out in the country you are on a main street. In spite of it all, Gunnison wears an aspect of resignation, as if to say 'it is better to have boomed and bust, than never to have boomed at all.'

The next day, September 14, we started for Crested Butte, the centre of an important coal region.

The road follows the main branch of the Gunnison, a famous trout-stream known to every follower of Izaak Walton; the valley broadens at times into a goodly expanse of farm-land, dotted with cheerful homesteads. A few miles below Crested Butte the river is flanked by mountains, among which the rhyolite cone of Round mountain and the basalt-capped mass of Mt. Wilkinson are conspicuous. Finally the traveler reaches the confluence of several streams and a wide basin, on the western edge of which the town of Crested Butte has been built. A noble mountain, buttressed with steep cliffs and massive as an anchorage for an aërial tramway to Mars, overlooks the town from the east, and has given it the name of Crested Butte. It is a big stock of porphyrite.[84] On the west and south the gentler slopes of Mt. Wheatstone, fringed with pines, merge with the valley, and to the north a perspective of successive peaks indicates the Ruby range. These gain height and mystery as seen through the smoke from the coke-ovens of Crested Butte, lying huddled under the long shadows of evening. In the centre of the town we found a barrack-looking building, which turned out to be a clean and comfortable hostelry. Next day, the 15th, saw us on the Coal Creek road, on our way to Irwin and Floresta. On both sides of the cañon the hillslopes were a desolation of burnt timber, a glimpse of that destruction, through careless fires, which is

[84] Crested Butte Folio. U. S. Geological Survey. 'Igneous Rocks,' by Whitman Cross.

Mt. Teocalli. A Highland Meadow

AFTER RIDING 400 MILES

T. A. Rickard, Lionel Lindsay, C. H. Wittenoom, H. N. Tod

gradually causing the deforestation of Colorado. The actual burning of good trees is bad enough, but the effect of such fires on the young growth does the more serious injury to the possibilities of a future supply of timber from these devastated tracts of mountain-land.

As the higher altitude was gained, the scenery improved and became bolder. We were passing through a porphyrite country, and the large fragments that had rolled to the roadside showed handsome crystals of feldspar. A winding trail took us northward from the westbound road and brought us to the deserted hamlet of Irwin. The Irwin mining district was active in 1880 and succeeding years. The Forest Queen mine is credited with a production of over a million dollars. In 1893 the fall in the price of silver flattened out the life of the camp, and until lately it has remained practically deserted. Quite recently a consolidation of a group of mines has been effected, and there is now promise of some activity. We visited the Ruby Chief mine, under the kind guidance of Mr. P. F. Ropell.

The Ruby Chief vein traverses a bedded series of coarse sandstone and shale belonging to the Ruby formation of the Upper Cretaceous. The vein occupies a fault-fracture, as was indicated by a break in the continuity of a layer of shale seen underground. The strike is northeast-southwest, while the dip, northwestward, departs only slightly from the vertical. The accompanying sketch, Fig. 12, gives a

typical section of the lode. In the foot-wall there is a band of shale. From *A* to *B* is a laminated casing of sandstone seamed with veinlets of quartz, which exhibits comb structure. *B C* is a 6 to 8-inch vein of white quartz, streaked with arsenical pyrite, or mispickel. This is the best ore. It usually carries ruby silver (proustite) and brittle silver (stephanite). Selected ore contains 65 to 100 oz. silver, and from 10 dwt. to one ounce of gold, per ton. This vein or 'leader,' *B C*, is usually characterized by a defined streak of pyrite, accompanied by zinc-blende, which speckles the quartz in lines parallel to the walls of the vein. *C* to *D* is mottled, obscurely brecciated country, with quartz surrounding the fragments of sandstone, and impregnated with arsenical pyrite. *D* to *E* is an outer band of obviously brecciated sandstone containing but little evidence of mineralization. The crystalline quartz, lining cavities or 'vugs,' is a marked feature of the lode, and especially of the independent quartz-veins that occur in the outer country alongside of the main vein. The quartz incrusting the brecciated sandstone within the lode, appears banded, due to the contrast between layers of quartz and mispickel. Rhodochrosite was seen in a few specimens. Mr. Ropell informed me that the best ore had been obtained from the vein at the horizon where it traversed the conglomerate beds, which form an integral portion of the Ruby formation. To these notes may be added the fact that porphyrite occurs in the vicinity. Mr. S. F. Emmons has noted that the

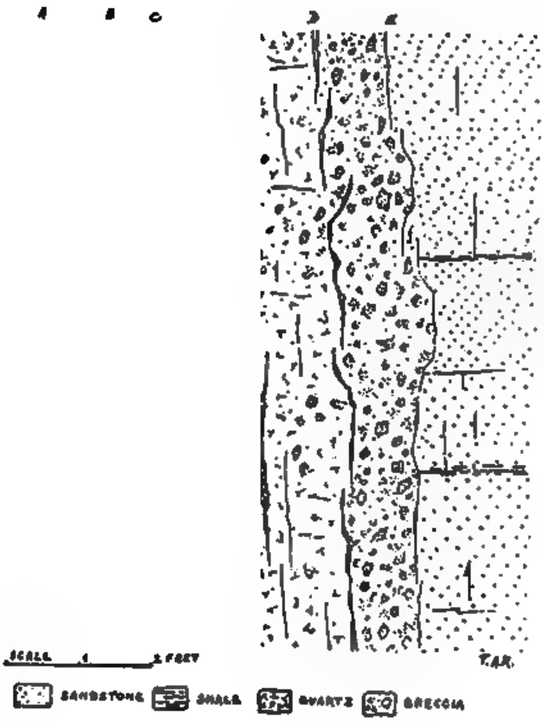

FIG. 12.

porphyrite occurs apparently as an intrusive sheet following the bedding of these sedimentary rocks, although the compound fracturing associated with the vein-structure "often gives it the appearance of a dike within the mineralized zone."[35]

Leaving Irwin, we retraced our steps for a mile and crossed the shoulder of Ohio peak at Kebler pass, named after the president of the Colorado Fuel & Iron Company. The winding road was followed through a pine forest until, on the northwestern slope of the ridge, it descended abruptly into a narrow ravine. To ride over a deserted mountain road and then to come suddenly into full view of a compact little mining settlement is a sensation which does much to break the monotony of cross-country riding. This was Floresta, boasting the only anthracite mine west of Pennsylvania. The old anthracite mine, known as Smith's, near Crested Butte, has been worked out, and the new anthracite region, tributary to Paonia, now being prospected between the Gunnison river and the Anthracite range, is yet in an immature stage of development.

A note on the Smith anthracite mine will be proper here. It was located 21 years ago, and opened in 1882 by George Holt, now of Chicago, Howard F. Smith, now of Elkhart, Indiana, and Dr. William A. Bell, of Colorado Springs. They erected a breaker, installed the requisite machinery and operated it for

[35] Anthracite-Crested Butte Folio. United States Geological Survey. 'Description of the Elk Mountains,' by S. F. Emmons.

several years, until it was acquired by the White Breast Fuel Company, in which Messrs. J. A. and J. T. Kebler were interested. Shortly afterward it was acquired by the Colorado Fuel & Iron Company, which has since held and steadily worked the mine until April, 1903, when it was finally abandoned as worked out.

The vein averaged from three to four feet in thickness, and the coal was of excellent quality. An approximate production of 5,000 tons per month was maintained. A spur of the Denver & Rio Grande Railroad from Crested Butte connected with the breaker. The incline from the mine to the breaker is 1,800 feet long, with a pitch of 45°; it is the longest and steepest in the State. The gravity system was employed.

UPTURNED STRATA OF THE WEST SLOPE OF THE ELK MOUNTAINS.

The light-shaded stratum, Jura-Trias; that to the right of it, Carboniferous; to the left, Cretaceous. From Hayden's Report of 1874.

Chapter 18

THE COAL MINE AT FLORESTA — HOW ANTHRACITE IS FORMED — METHODS OF MINING — THE BREAKER — A PANORAMIC VIEW.

THE coal seam at Floresta is three feet thick, and dips north at an angle of about 20°. It lies with the hillslope, the ravine having cut into the seam so as to give a line of outcrop on both sides. The agency that was chiefly instrumental in the development of anthracite from bituminous coal is indicated by the porphyrite, which appears in the form of dikes in the railroad cutting and is clearly to be seen capping the hillside. The coal now being exploited occurs at a geological horizon which is 115 feet above the base of the Laramie formation, belonging to the Cretaceous. There is also another, poorer seam, one hundred feet higher. These coal-measures are covered by a sheet of porphyrite, which extends for more than a mile along the north slope of the Anthracite range, the name of the much serrated ridge behind the mine. The metamorphic effect of the porphyrite on the coal is readily apparent; where the metamorphism of the sedimentaries is least, noncoking bituminous coals are found; where the meta-

The Portals of the River. (See Page 121.)

Mt. Sneffels. (See Page 130.)

morphism has been present, but not severe, the coking coals occur; and in regions of intense local metamorphism the coal has been changed to anthracite. It has also been observed[88] that a dike cutting across a coal seam affects its chemical and physical composition for a short distance only, but an intrusive sheet will affect it for a greater distance and over an area commensurate with the extent of the eruptive itself.

The output of the mine at the time of our visit was 100 to 125 tons per day. The manager, Mr. Thomas McLaughlin, to whom we were indebted for many courtesies, informed me that there is much difficulty in keeping miners at Floresta, because the mine is not in operation, on account of snow, for more than half the year, which prevents men with families from going there. Moreover, the narrowness of the seam and the conditions of working are such that only the most experienced miners can earn a good living. The work is much more arduous than that of ordinary lode-mining, because of the cramped space and the subsequent disposal of the output. Owing to the slight dip of the seam, it is difficult to handle the coal underground; the chutes that carry the product of the face to the entry are made of No. 16 steel sheets, 3 feet wide, laid on the foot-wall, and nailed onto sides made of 2 by 6-inch scantling. When in constant use the angle of inclination is sufficient

[88] George H. Eldridge, Anthracite-Crested Butte Folio. United States Geological Survey.

to keep the chute clear, but if the steel lining becomes at all rusty, the slope proves inadequate for the automatic descent of the coal, and the miner jumps into the chute and toboggans down the incline, pushing the coal before him with his feet. The men get 90 cents for 2,600 pounds, of which it is estimated that 2,000 pounds is clean coal, the balance going over the culm heap. Wages, as I got them from a scrutiny of the pay-rolls, averaged $4.25 per day, with about 30 men at work. The men are largely Austrians; scarcely one-half of the miners speak English.

In the mine we found that pillars to support the roof were left 15 feet wide, while the rooms or stopes were 25 feet across. The drilling is done with machine-augers, the hole being begun with a 2½-inch bit, and finished with a 1½-inch. Holes are made from 4 to 6 feet deep. Coarse black powder is used; it costs the miners $3 per keg of 25 pounds. The product of the mine is sent to the breaker, which has a capacity of 600 tons per day. Five sizes are made. The coal from the tipple goes over two sets of screen-bars, the fine passing direct to the picking-tables and the lump to the breaking-rolls. These are toothed rolls of the usual type. Then follow revolving screens. The culm is hand-picked as it runs down the chutes. These chutes for slate-picking are double. Each picker (boys and old or crippled miners) draws past him just as much coal as he can thoroughly clean, so that the coal is handled once only.

The upper landing is 10,175 feet above sea-level. This makes Floresta the highest coal mine in the United States, if not, indeed, the highest in operation

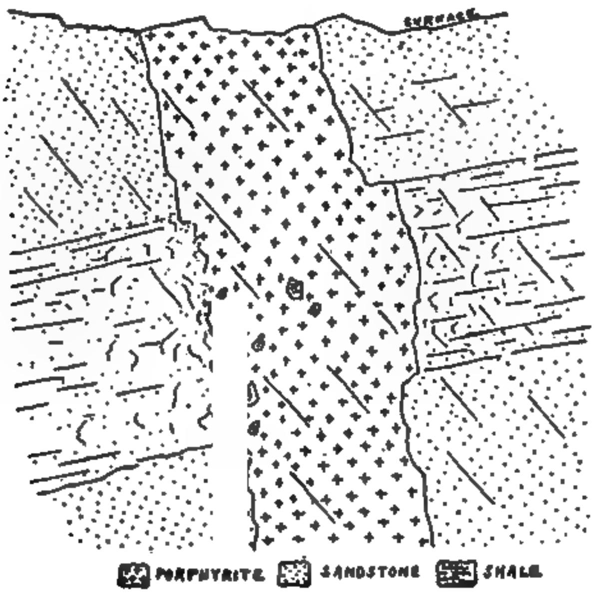

FIG. 13.

anywhere. An average analysis of the anthracite shows:

	Per Cent.
Fixed carbon	87.51
Volatile combustible	7.62
Moisture	0.72
Ash	4.15

The roof of the seam is a 30-foot bed of sandstone; the floor is in shale. Along the railroad grade

GEOLOGICAL MAP OF THE ANTHRACITE REGION.
After the U. S. Geological Survey.

there are afforded several good sections of the sedimentary rocks enclosing the coal, where they are intruded by porphyrite. A typical section (Fig. 13) exhibits a dike, evidently a porphyrite containing large distinct crystals of feldspar. The bed of shale traversed by the dike is hardened near the porphyrite, and otherwise altered into a dark massive rock. Fragments of shale are included within the dike. The joints in the sedimentaries cross the dike clearly, and are, therefore, later than the intrusion of the latter. There is no distinct parting or wall between the sedimentaries and the eruptive.

On the railroad grade, and about a mile from Floresta itself, a promontory of rock gives a magnificent view of the Anthracite and Ruby ranges. To the left are dark pine woods sloping from Ohio peak with an inclination that reproduces the dip of the porphyrite flow and the coal-beds underneath; in the middle distance, and contrasting with the dark array of pines, are brilliantly tinted foothills whose rounded contour indicates the softer sandstones of the Cretaceous. Beyond these rises the abrupt mass of Mt. Beckwith, built of porphyrite. Above the northern horizon is Gothic Mountain; to the right, and coming down to meet the other half of the picture, is the red Ruby range with its serrated comb of dikes, which can be seen extending in jagged line down to the valley itself, through which a trout-stream winds in and out until it is hidden by the precipitous face of

Mt. Marcellina, a dome-shaped laccolith[67] of porphyritic diorite. Far off, palpitating amid the haze of forest fires, are ranks of distant hills whose purple

THE LACCOLITH OF MT. MARCELLINA.
After Whitman Cross.

forms are faintly silhouetted against the flawless blue of a Colorado sky.

[67] A 'laccolith' is a body of intrusive lava. It does not spread in dikes or sheets, but gathers into a mass or core, which lifts the overlying strata.

Chapter 19

OVER THE OHIO PASS—AT GUNNISON AGAIN—FISHY YARNS—THE RIVER PORTALS—POETRY AND GEOLOGY.

LEAVING Floresta the next morning, September 16, we crossed the Ohio pass, on our return to Gunnison, by a road different to that of our previous journey, which had now taken us around a group of three mountain peaks, Mt. Wheatstone, Mt. Axtell, and Mt. Carbon, and from the watershed of the Slate river to that of Ohio creek, both tributaries of the Gunnison, into which they merge a little to the north of the town itself. Ohio pass, 10,033 feet above sea-level, is similar to other mountain crossings; there is a defunct sawmill with an untidy heap of sawdust; an abandoned railroad grade, as though engineering skill had failed of breath; a scattering of pines, the straggling procession representing the survivors of those serried ranks that came up the mountain-side in proud array until they encountered an invisible bar to further advance—the 'timber line' which, like the shore of an ancient sea, belts all the mountains and marks the upward limit of the conditions favorable to forest growth.

We passed Carbon and Castleton, two coal camps, with all the hideousness that belongs to such settlements; then a short stay, pleasant for man and horse alike, at a roadside ranch, prepared us for a long canter over the wide dusty road, which finally, but we could never tell when, brought us into the unlimited city of Gunnison.

That night at Gunnison we heard the fishermen's tales. It is a great resort for the manipulators of rod and line. It is also a mining centre for the surrounding hill-country, so that there is no lack of fishy yarns. The unwary will hear of mountains of iron and acres of gold ore; but behind the exaggeration there is the fact that the Gunnison country, with the Elk mountains to the north and the granite foothills that lead to the San Juan ranges, to the south, is extremely rich in a variety of mineral wealth—coal, iron, gold, and silver—which would have undergone more substantial exploitation if the windy breath of a premature boom had not blighted it in the infancy of its development.

On September 17 we rode from Gunnison to Gate View. The road follows the Gunnison until it crosses the river at Iola, the shipping point of the Vulcan district. Taking a cross-country trail, we filed through the sage-brush covering monotonous low hills, the remnants of granite mountains that had yielded to the leveling hand of Time. Spencer and Dubois, two mining camps, were found almost deserted. Then, surmounting a ridge, we saw again

the splendor of the San Juan ranges and the pleasant valley of the Lake Fork. After weary miles of sage-brush hillocks it was singularly refreshing to look upon a landscape through the diversified beauty of which the modifying influence of geological structure could be plainly discerned. At Gate View we passed a night. The name is given to a ranch and railroad section-house near the natural gateway of the Lake Fork, which flows through a gap cut in the andesite. A tongue of this eruptive crosses the broad valley; the river has cut its way through; high, nearly vertical, cliffs arise on either side; then steep débris slopes, making a broad V, at the bottom of which the road, the railroad, and the river jostle each other for passage; this framed a view of hills rich in the gold and russet of the aspens, surmounted by the high peaks of the San Juan mountains.

Looking through the portals of the river, one is reminded of Ruskin's question concerning a similar natural structure: "When did the great spirit of the river first knock at those adamantine gates? When did the porter open to it and cast his keys away forever, lapped in whirling sand?" It is a fine similitude; but geology, with less poetic diction, says that the rock is not adamant to the instrument of erosion as used by the running stream with patient persistence through long time, and that no porter was needed to open the gate; the river found a way by obeying the laws of its being—gravity, which impelled it to seek the lowest channel and to deepen that channel

continually, for fear the onlooking hills should fill it up too fast with their discarded débris.

The road, farther on, alternately crosses flat stretches of partially cultivated land and descends into the bed of the stream amid narrow gorges cut into andesite-breccia and tuffs, until at the confluence of Henson creek we rode, under a sharp downpour of cold rain, into the town of Lake City.

Gothic Mountain. A Trachytic Mass Overlying Cretaceous Rocks.
After James D. Dana.

Chapter 20

LAKE CITY — THE UTE & ULAY MINES — CONCENTRATING MILL — ELECTRICAL DRILLS — ROUGH HANDLING — NEW MILLS.

WE reached Lake City at noon amid a rainstorm which was remarkable for the reason that it was the first bit of bad weather encountered during twelve days. It cleared in the afternoon, so, leaving our horses to rest, we walked the seven miles up Henson creek to the Ute & Ulay mines. These have been the mainstay of Lake City through all the vicissitudes of the past twenty years. The two veins have been worked at various times both jointly and separately. When I was last there the Ulay lode was the chief source of production; on the present occasion we found that the Ute vein was affording the principal stoping ground. This was above the main adit. The vein is from four to five feet wide; it is a simple quartz vein containing argentiferous galena. Iron pyrite and zinc-blende are present in relatively small quantity. The lode is essentially an impregnation following a sheeted band in the andesitic breccia of the San Juan formation and has the characteristics already noted at the Camp Bird, Smuggler Union,

and other mines in the same region. Stopes extend, nearly continuously, for half a mile. The Ute dips westward at 63° and is worked in the adjacent California mine. The Ulay has been worked 700 feet below Henson creek through old workings, which were in bad repair; a new vertical shaft had just been started to open up the lower ground on this lode.

The mill reminded me, in its method of treatment, of the old Foxdale mine, in the Isle of Man, where, however, raff-wheels are used instead of elevators and the plant is spread over a much larger area. The treatment is simple and well adapted to the character of the ore. The mill has a capacity of 90 to 100 tons per day. The ore goes first to a rock-breaker (Blake, 9 by 15 in.) and then to three sets of rolls (Allis-Chalmers, 16 by 30 in.), then through four successive trommels, 36 in. diam. and 7 ft. long, which size the crushed ore to 8, 6, 4, and 2½ millimetres. The coarse, which passes through the trommels, goes to the jigs, a double-compartment jig for each trommel. The fine, which escapes from the last trommel, passes into two hydraulic sizers, the coarse being sent to jigs, while the fine goes into a third sizer. The coarse from this last sizer goes to a jig and the fine runs to the buddles. There are two plain buddles, 16 ft. diam., and four double-deck buddles, 24 ft. diam., the tailing from which passes into settling-vats, where the slime is arrested.

The concentrate is dried and mixed by passing through a heated revolving cylinder. About 1½ per

cent of moisture is left in the concentrate, in order to lessen the leakage arising from the bad flooring of the railroad cars, which would be a greater source of loss if the concentrate were dry enough to run readily. The concentrate contains 58 to 61% lead, 13 to 15 oz. silver and 0.05 to 0.06 oz. gold per ton; this represents about 16% in weight of the original ore and an extraction of about 80% of the lead and 65% of the silver.

Next day, September 18, saw us started on our final stage, from Lake City to Ouray. The road took us again past the Ute & Ulay, where we stopped to get some further data from the millman. As we rode up Henson creek it was pleasant to notice a good deal of mining activity; we passed under the Bleichert tramway of the Hidden Treasure, past the Moro mill, with a Leschen tram connecting it to an unseen mine on the pine-clad mountain-side, and then, just below Rose's Cabin, the Bonanza tunnel, with a new mill in course of construction. Mr. Philip Newitt, superintendent of the Henson Creek Lead Mines Company, as it is officially styled, was kind enough to take us underground. The lode is the usual sheeted band of andesite-breccia, carrying four to five feet of quartz, in which gold, silver, copper, and lead are carried by copper pyrite, galena, and other less conspicuous minerals.

This mine afforded an example of the use of electric drills; the Gardner and Durkee were both in use and the superintendent expressed himself as dis-

appointed with them; in each case the motor is carried on a truck and power is transmitted through a flexible shaft. The practical efficiency of the electric drills is a subject too large for passing comment, though it is fair to the inventors to say that the machines suffer from their unpopularity among miners and the frequent lack of technical skill on the part of the operator. As a rule the first drill tested in a mine is handled by an expert provided by the company that sells the drill; then, results being deemed good by a manager or director, others are ordered. The drill company's man and his skilled assistants depart, leaving a delicate piece of electrical machinery to the tender mercies of a muscular workman, who starts with a prejudice against anything new and unfamiliar, and is apt to be confirmed in his prejudice by his own inexpert handling of the machine. This, of course, is, in a way, the drawback to all electrical machinery —it requires workmen who know something about it—but it is an obstacle that the increasing application of electricity will overcome, surely. In the meantime I unite with others in the hope that the electric drill will be further improved, because it can facilitate and cheapen mountain mining to an extraordinary degree.

Chapter 21

ROSE'S CABIN — CLIMBING THE RANGE — A SNOW-STORM — BEAR CREEK — AFTER THE STORM — A GLORIOUS PICTURE — ARRIVAL AT OURAY — THE END.

ROSE'S CABIN, at 10,850 feet, just above the Bonanza mine-buildings, is a landmark. It was a stopping place in the old days of transmontaine travel when long lines of pack-mules and horsemen were wont to file up Henson creek on their way to Silverton, Rico, and Ouray. We took the right-hand trail, past the Palmetto mill and along the old grade to the Frank Hough mine.

As we climbed the range, the snow-mists gathered, and when we finally reached the crest, at 12,850 feet, the mountains were robed in all the magnificence of the storm. The cold blast from the cañon below swept up to the summit of the range, driving a chilly mist, which flung itself fiercely around every crag and threw great shadows that stalked swiftly across the darkening slopes. Here and there amid the gloom a lonely peak caught the light, a Titan head above the sea of cloud. Thus we saw old Uncompahgre and the Wetterhorn, besides many another unnamed

crest. While we waited, the hail and snow came fast, and so, without further delay, we began the slow descent of the other side, leading and pulling our shivering horses down the tedious talus slopes.

Soon we reached the warmer air of Bear creek basin, a spacious amphitheatre near the timber-line, from which a well-marked trail took us into Bear creek cañon, a narrow gorge, lined by the most astounding precipices and picturesque to a degree that was astonishing even after two weeks of mountain scenery. The andesite-breccia, in nearly level layers, forms cliffs that sweep from an eerie height of a thousand feet, and more, down into the hidden bed of a torrent. The sheeted structure, due to parallelism of nearly vertical fractures, is noticeable, and the sympathetic structure of the veins is apparent even at a distance, for their outcrops are clearly visible, ribbing the rock faces with broken lines of quartz.

We passed the Yellow Jacket and the Grizzly Bear mines, huddled under the beetling brows of breccia cliffs, where, here and there, a cluster of courageous pines clung hungrily for life, or a solitary cabin looked calmly over the abyss, or faint trails in unexpected tracery of line wound in and out of dark ravines with the veritable unconscious air of gentlemen without visible means of support.

Our progress, over a trail which was a narrow, albeit quite safe, ledge between rock and torrent, was necessarily, with horses, a slow business. At length, after hours of a continuous descent, which seemed

After the Storm. On the Crest of the Range

OURAY

Mt. Abram in the Background

interminable and gave us a singular feeling of going right into the depths of the earth, we emerged suddenly into full view of the Uncompahgre valley. It is no exaggeration to say that all four of us, some of whom had made the voyage round the world more than once, were amazed at the grandeur of the great picture before us. Scattered already to the four winds, as becomes mining engineers,[28] we shall, I believe, always remember that "polychrome of splendor, an exultation to recall." Ruskin would have rhapsodized over it and Clarence King could have described it.[29]

The storm had swept northward, the sky was still partly overcast with flying cloud, a luminous atmosphere, pure as interplanetary space, filled the cañon depths, and from the west the sunlight pierced the lingering mists with mellow light. We stood on a narrow promontory. Across the cañon the terraced slopes descended in parklike gradation, resplendent with the livery of autumn, and above their aspen gold the bastions of blue-gray andesite rose tier after tier in Gothic severity of line until belted with the rising mists. Up the valley to the left the winding thread of the river led to the pyramid of Mt. Abram, his sentinel head aglow with sunlight, while farther south rose the Red mountains, shrouded

[28] One is in Western Australia, another in California, the third is in Mexico, and the fourth in New York City.

[29] This gives me the opportunity of recommending to my friends that most delightful book of Clarence King, 'Mountaineering in the Sierra Nevada.'

in cold vapor that dimmed their volcanic tints. Straight in front and northward, overtopping these swiftly changing visions of rich coloring and sculptured line, there gleamed the Mt. Sneffels ranges, freshly ennobled by a coronet of snow, with a great passion of light glowing about their lordly summits, while in the darkening east there trailed away "a gray-winged form, the ghost of wind and rain."

It will seem something of an anti-climax to state that the trail subsequently led us to an interesting geological section, where the breccia of the Eocene period was found resting upon the upturned edges of pre-Cambrian slates and quartzite, with only a thin layer of conglomerate, possibly a representative of the Telluride formation, between them. We reached Ouray before dark, having completed a ride of fully 400 miles.

"For what high end is all this daily boon,
  Unseen of man, in sightless silence spent?
Doth lavish Nature vainly importune
  The unconscious witness of the firmament?

"Or, is it that the influent God, whose breath
  Informs with glory sea, and shore, and hill,
His infinite lone rejoicing nourisheth
  Upon the bounteous outcome of His will?
—*Brunton Stevens.*

SCOTT TURNER